

January 1925

Botanical Series

Vol. XIII, No. 5

Memoirs of the Department of Agriculture in India

THE ERADICATION OF *CYPERUS ROTUNDUS* L.
(A STUDY IN PURE AND APPLIED BOTANY)

BY

S. B. RANADE, B.A., M.Sc. (Bom.)

(Under the Direction of a Research Committee of the Bombay Department
of Agriculture)

ARRANGED AND WRITTEN

BY

W. BURNS, D.Sc. (Edin.)

Economic Botanist, Bombay



AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Price, Rs. 2-4 or 3s.

EDITED BY

The Council of the Pusa Agricultural Research Institute, which
is not, as a body, responsible for the opinions expressed in
the Memoir.

January 1925

BOTANICAL SERIES

VOL. XIII, No. 5

MEMOIRS OF THE
DEPARTMENT OF AGRICULTURE
IN INDIA

THE ERADICATION OF *CYPERUS ROTUNDUS* L.

(A STUDY IN PURE AND APPLIED BOTANY)

BY

S. B. RANADE, B.A., M.Sc. (Bom.)

*(Under the Direction of a Research Committee of the Bombay Department
of Agriculture)*

ARRANGED AND WRITTEN

BY

W. BURNS, D.Sc. (Edin.)

Economic Botanist, Bombay



AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Agents for the Sale of Government Publications

IN THE UNITED KINGDOM

- | | |
|---|--|
| Constable & Co., 10, Orange Street, Leicester Square, London, W.C. | W. Thacker & Co., 2, Creed Lane, London, E.C. |
| Kegan Paul, Trench Trübner & Co., 68-74, Carter Lane, E.C., and 39, New Oxford Street, London, W.C. | Luzac & Co., 46, Great Russell Street, London, W.C. |
| Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W. | Wheldon & Wesley, Ltd., 28, Essex Street, London, W.C. |
| P. S. King & Sons, 2 and 4, Great Smith Street, Westminster, London, S.W. | B. H. Blackwell, 50 and 51, Broad Street, Oxford. |
| H. S. King & Co., 65, Cornhill, E.C., and Pall Mall, London, W. | Deighton, Bell & Co., Ltd., Cambridge. |
| Grindlay & Co., 54, Parliament Street, London, S.W. | Oliver & Boyd, Tweeddale Court, Edinburgh. |
| T. Fisher Unwin, Ltd., 1, Adelphi Terrace, London, W.C. | E. Ponsonby, Ltd., 116, Grafton Street, Dublin. |

ON THE CONTINENT

- | | |
|--|-------------------------------|
| Ernest Leroux, 28, Rue Bonaparte, Paris. | Otto Harrassowitz, Leipzig. |
| Martinus Nijhoff, The Hague, Holland. | Friedlander and Sohn, Berlin. |

IN INDIA AND CEYLON

- | | |
|--|--|
| Thacker, Spink & Co., Calcutta and Simla. | Thacker & Co., Ltd., Bombay. |
| W. Newman & Co., Calcutta. | D. B. Taraporevala, Son & Co., Bombay. |
| R. Cambray & Co., Calcutta. | Radhabai Atmaram Sagoon, Bombay. |
| S. K. Lahiri & Co., Calcutta. | Sunder Pandurang, Bombay. |
| B. Banerjee & Co., Calcutta. | Gopal Narayan & Co., Bombay. |
| The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca. | Ramchandra Govind & Son, Kalbadevi, Bombay. |
| Butterworth & Co. (India), Limited, Calcutta. | Proprietor, New Kitabkhana, Poona. |
| The Weldon Library, 57, Park Street, Calcutta. | The Standard Bookstall, Karachi. |
| Rai M. C. Sircar Bahadur and Sons, 75-1-1, Harrison Road, Calcutta. | Mangaldas Harkisandas, Surat. |
| Standard Literature Co., Ltd., Calcutta. | Karsandas Narandas & Sons, Surat. |
| Lal Chand and Sons, Calcutta. | A. H. Wheeler & Co., Allahabad, Calcutta and Bombay. |
| Association Press, Calcutta. | N. B. Mathur, Superintendent, Nazir Kanun-i-Hind Press, Allahabad. |
| Higginbothams, Ltd., Madras. | Munshi Seeta Ram, Managing Proprietor, Indian Army Book Depôt, Juhu, Cawnpore. |
| V. Kalyanarama Iyer & Co., Madras. | Rama Krishana and Sons, Lahore. |
| G. A. Natesan & Co., Madras. | Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore. |
| S. Murthy & Co., Madras. | Superintendent, American Baptist Mission Press, Rangoon. |
| Thompson & Co., Madras. | Manager, the "Hitavada," Nagpur. |
| Temple & Co., Madras. | S. C. Talukdar, Proprietor, Students and Company, Cooch Behar. |
| P. R. Rama Iyer & Co., Madras. | A. M. & J. Ferguson, Colombo, Ceylon. |
| Vas & Co., Madras. | |
| E. M. Gopalkrishna Kone, Madura. | |

CONTENTS

	PAGE
I. INTRODUCTION	99
II. THE BOTANY OF <i>Cyperus rotundus</i> L.	101
1. Systematic position	101
2. Common characters and names	102
3. Varieties	102
4. The seedling stage and first tuber	104
5. The geophilous habit	105
6. Other tuber-forming species	107
7. General morphology and physiology of the tubers	107
8. General ecology of <i>Cyperus rotundus</i> L.	109
9. The anatomy of <i>Cyperus rotundus</i> L.	109
III. EXPERIMENTS IN THE PROPAGATION OF <i>Cyperus rotundus</i> BY SEED	113
IV. EXPERIMENTS IN THE PROPAGATION OF <i>Cyperus rotundus</i> BY TUBERS	120
1. Experiments in deep planting of tubers	125
2. Experiments in damaging the tubers	135
(a) by wounding	136
(b) by exposure	136
3. Experiments on the effect of spraying with various chemicals	142
4. Experiments in repeated removal of the shoots	147
5. Experiments in the effect of artificial cover	157
6. Experiments in the competition of other plants with <i>Cyperus rotundus</i>	164
7. Experiments on the effects of cultivation and cover crops	170
V. GENERAL CONCLUSIONS	177
APPENDIX	181

THE ERADICATION OF *CYPERUS ROTUNDUS* L.

(A STUDY IN PURE AND APPLIED BOTANY).

BY

S. B. RANADE, B.A., M.Sc. (Bom.)

(Under the direction of a Research Committee of the Bombay Department of Agriculture).

ARRANGED AND WRITTEN

BY

W. BURNS, D.Sc. (Edin.),

Economic Botanist, Bombay.

I. INTRODUCTION.

"THE contributions of scientific research to agricultural development in the past have been enormous. In fact the entire structure of modern agriculture is founded on scientific discoveries. It will, however, only require a hasty and superficial survey of the situation to indicate that the opportunities for still further contribution are even greater at this time than they have ever been in the past. Certain fields of agricultural research have been almost entirely neglected up to the present time. Probably the most outstanding one is the weed problem. Weeds undoubtedly do as much to reduce the annual crop as do insect pests or plant diseases and yet they are just beginning to receive attention."¹

The research described in this memoir has been done under auspices and in a manner which themselves deserve a short description.

¹ *Research Work of the Department of Agriculture*, by E. D. Ball, Director of Scientific Work, U. S. Department of Agriculture, in the *Chemical Age*, article copied in full in the *American Fertilizer*, Jan. 26th, 1924, pp. 62-68.

The Trustees of the Sassoon David Trust Fund, Bombay, have from time to time made grants for research work in connection with agricultural development. In the present instance, they supplied the means "for the investigation of the eradication of the most serious weeds of cultivation, and especially of the *Lavala* weed," this purpose being so outlined by the Director of Agriculture, Dr. H. H. Mann, in making his proposals.

It was early decided to concentrate on the *lavala* weed, *Cyperus rotundus*. All writers agree as to the noxious character of this weed. Cooke¹ says, "A very troublesome weed of cultivation, eradicated with difficulty owing to the stolons becoming woody." Roxburgh² states, "This is by far the most common species we have in India; it delights in a moist sandy soil though it grows abundantly everywhere. It is by far the most troublesome weed we have in our gardens, there is no extirpating it as every little bit of the root grows readily." This character is confirmed by a remark in a recent American publication,³ that "nothing serves so well to propagate it as to plough and re-plough with a view to destroy it."

In a letter to the Sassoon David Trust Fund Trustees in 1920 the then Director of Agriculture of the Bombay Presidency, Mr. Keatinge, said, "The problem of eradication, particularly in some of our most fertile areas like Kaira and Gujarat, is an unsolved problem, and the *lavala* weed itself probably reduces in these very fertile tracts annually the yield by 25 to 30 per cent."

The plant is widely distributed in all warm regions. It is impossible to locate the centre of that distribution. It is found in Australia, America, Africa, and the warmer parts of S. Europe, and, in fact, anywhere in the tropics, sub-tropics and adjacent regions.

Its main peculiarity and its main strength are the tubers formed on its underground wiry rhizomes, by means of which it stores up food and propagates itself.

The organization of research in general and agricultural research in particular is the subject of considerable discussion and trial in most countries at the present moment. In this, as in several other of our recent departmental researches, we have followed a method which has proved efficient and which seems to have found favour elsewhere also. This was to control the research by a committee in which various interests were represented and with a chairman whose own technical and administrative training would enable him to

¹ Cooke, J. *Flora of the Bombay Presidency*, II, 872, 1908.

² Roxburgh, W. *Flora Indica*, 66, 1874.

³ Georgia, Ada. *Manual of Weeds*, 68, 1914.

guide the actual worker or workers. The committee appointed by the Director of Agriculture consisted of—

The Economic Botanist to the Government of Bombay

(Chairman) Dr. W. Burns.

The Professor of Agriculture, Poona College of Agriculture

ture Prof. J. B. Knight,

and later Prof. B. S. Patel.

The Deputy Director of Agriculture, Gujarat .. Rao Saheb Bhimbhai Desai.

For the actual conduct of the research Mr. S. B. Ranade, B.A., M.Sc. (Bom.) Bombay, was selected. His work was planned by the committee and carried out under the personal supervision and with the assistance of Dr. W. Burns. The laboratory work was done in the laboratory of the Economic Botanist, College of Agriculture, Poona, and the field work on various farms of the Bombay Department of Agriculture, on certain privately owned fields and in the Empress Gardens, Poona.

The object of this research was to find means of eradicating the lavalava weed. This is not the first time that departments in India and elsewhere have addressed themselves to this problem. Their method of attack has usually been experiment on a field scale with agricultural implements.

After careful consideration the committee came to the conclusion that there was really only one sound way of dealing with this problem, namely, to study the lavalava weed itself first, and get to know all that one could about its life cycle, and then to attack it at the weakest point of that life cycle.

It was recognised that this meant in the beginning a botanical enquiry with possibly slow progress, but that the foundation of sound scientific knowledge so laid would bear the weight of any superstructure of agricultural practice that might be built up as the result of that work.

The results have entirely justified the method of controlling the research, the choice of the actual worker, and the decision to study first the plant and only later to deal with field practice.

The whole research is here described.

II. THE BOTANY OF *Cyperus rotundus*, L.

1. *Systematic Position.*

The natural order *Cyperaceæ* is a well-defined family, superficially similar to grasses but differing actually in many essential points, both botanically and agriculturally. It is not essential in this Memoir to go into these

details, which are available in any text-book. The genus *Cyperus* itself belongs to the sub-family of the *Scirpoideæ-Cyperineæ* and numbers about 400 species, mainly found in the tropical and sub-tropical regions of the earth. In South England there are two species, rare in occurrence.

Cyperus rotundus is cosmopolitan within the limits of distribution of the genus and is, in all the countries where it occurs, a formidable weed of cultivation. Possibly for this very reason it has not received that detailed study at the hands of botanists which rarer plants enjoy. In the various floras of India the plant naturally finds a place and we quote here Hooker's¹ description.

"India, alt. 0-6,000 ft., a pestiferous weed. Distrib. All warm regions.

Glabrous. Stolons slender, up to 4-8 in., hardening into wiry roots, thickened into black woody ovoid tubers $\frac{1}{3}$ -1 in. in diam., not (or very obscurely) zoned. Stems subsolitary, 4-32 in. at top triquetrous. Leaves long, often overtopping stem, $\frac{1}{6}$ - $\frac{1}{3}$ in. broad. Umbel frequently compound, primary rays 2-8 in., spikes loosely spicate of 3-8 spikelets; but umbel sometimes large, sometime reduced to 1 head and (in a common Calcutta form) to 1 spikelet." The plant is listed by Clarke² but not figured.

2. Common Characters and Names.

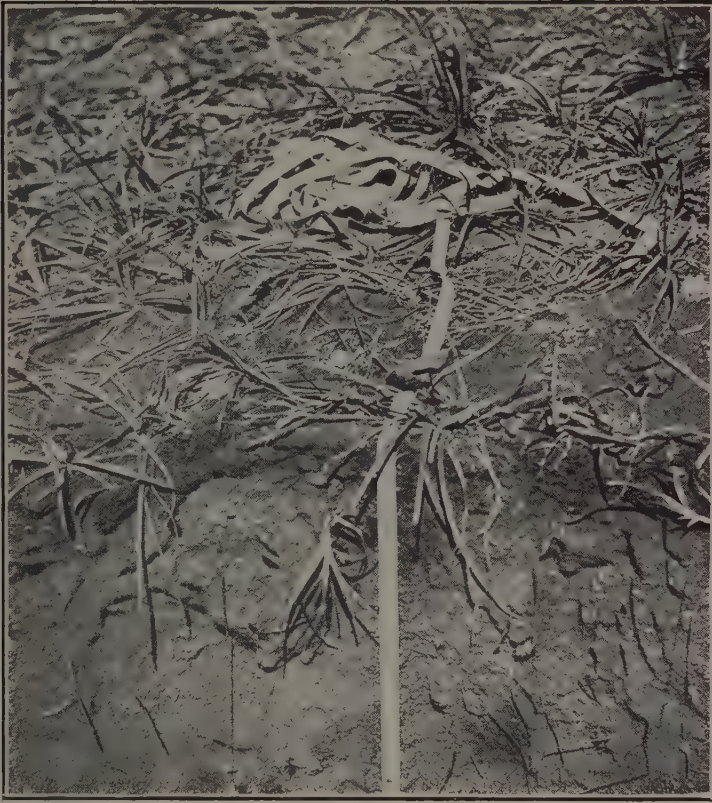
Cyperus rotundus is easily recognizable. Its leaves spring directly from the ground without any apparent stem. They are of a peculiar bright green and are marked by a deep furrow in the middle. When full grown they sprawl about on the surface of the soil. The plant thus has a characteristically untidy habit. (Plate I, 1.) From the centre of the rosette of leaves springs up the grass-like inflorescence. A plant so common, so detrimental to agriculture and so recognizable was bound to receive common names. In the Bombay Presidency its vernacular names are *Lavala* and *Nagarmotha* (in Marathi), *Gundardo* (in Gujarati), and *Korai Tek* (in Kanarese). The Tamil name is *Kizhangu*. Throughout this memoir, when referring to the plant by its common name, we shall call it *Lavala*.

3. Varieties.

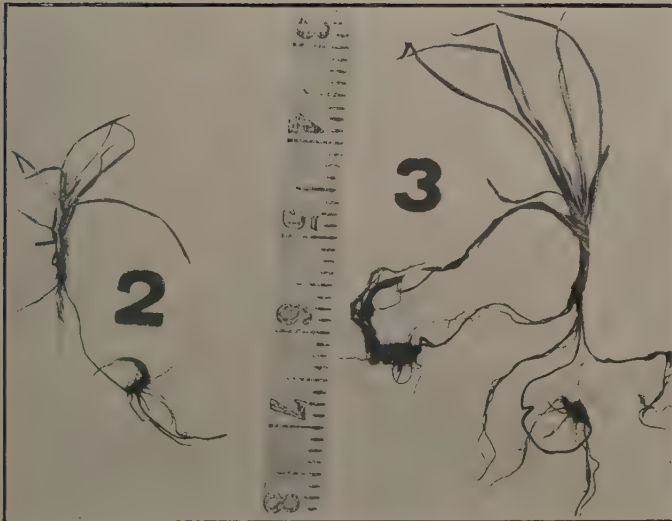
In Gujarat two forms of the plant are distinguished by the people and named Chido and Chidi. In Chido vegetative growth above ground is vigorous and the leaves are long and broad. Below ground the tuber formation is also vigorous, the tubers are long and broad, formed at large

¹ Hooker, J. D. *Flora of British India*, VI. 615.

² Clarke, C. B. *Botanical Sub-subareas of British India*, 36.



1. The Laval plant above and below ground.



2. The Laval seedling.

intervals on a deeply penetrating rhizome system. Most of these tubers do not sprout but remain as reservoirs of food and water. In Chidi the shoot⁸ are stunted and bushy, and the leaves small. The tubers are small and more superficially placed on a less extended rhizome system. As a matter of fact, most of the tubers are within a foot of the surface of the soil. These sprout readily and form a dense mass of shoots. It is believed that Chido turns into Chidi and that the latter is the more difficult to eradicate.

We found Chido on moist loose *goradu* (sand and clay) soil and in irrigated fields of black soil. Chidi was found in hard drying *goradu* soil, and also in water-logged or packed black soil. This would seem to indicate that Chidi was a response to unfavourable soil conditions. To test this, tubers of characteristic Chido and Chidi plants were dug up from various places in Gujarat and brought to Poona where they were grown in pots in various soils and conditions. It was found that the formation of the Chido and Chidi forms was absolutely dependent on the soil and water conditions, tubers from either Chido or Chidi giving the opposite form in their progeny according to the environment.

While the variation just mentioned is an effect of the environment and not inherited, there are variations as yet little studied which appear to be inherited. It has been our experience and also the experience of others that any wild species in India, if critically studied, yields sub-species of considerable range of variation. Hooker¹ has in the case of many of the grasses mentioned such. In the case of *lavalala*, the floras give the colour of the glumes as red-brown. We have in addition observed the following colour variations in the glumes, (1) yellowish white, (2) light red, (3) coppery red with a metallic lustre, (4) dark red with a blackish tinge. This colour variation has nothing to do with age, as the colour was determined at the same stage in each case, namely, the time when the stigmas were protruding. In 1921, experiments were made to determine if these colour variations were inherited through tuber propagation. It was found that this was so in all cases, with the curious modification of loss of metallic lustre in the third variety mentioned. We have not been able to pursue these experiments further but there is obviously here a fertile study for the geneticist.

It is noteworthy that Sedgwick², a very accurate observer, mentions these colour variations, and even goes the length of correlating them with soil variations. We are unable to confirm such correlation.

¹ Hooker, J. D. *Flora of British India*, VII, 192-193, *Andropogon monticola*.

² Sedgwick, L. J. The Cyperaceæ of the Bombay Presidency, *Bom. Nat. Hist. Soc. Jl.*, XXV, No. 4. p. 696, June 1918.

4. *The Seedling Stage and First Tuber*.

From the standpoints of both botany and agriculture, the tuber-forming character of this plant is of the greatest importance. A complete understanding of the nature and origin of these tubers demands a study of the plant from its seedling stage onwards. We shall now record our observations.

The visible "seed" is really a fruit, being a triangular compressed hard-coated and brown nut of minute size ($1/30$ th by $1/40$ th inch). Within this is the true seed, containing endosperm and a microscopic embryo. On germination this embryo produces a seedling of the type well-described by

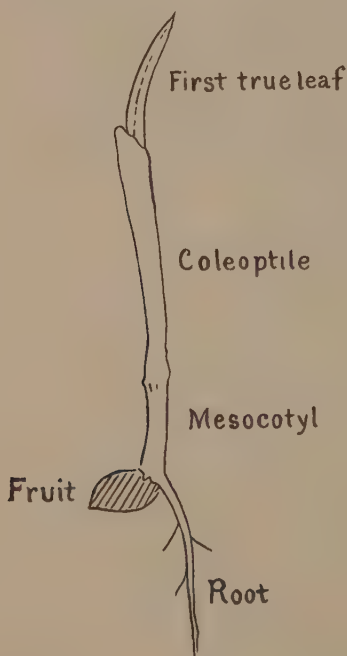


FIG. 1. Seedling of *Cyperus rotundus* L.

Goebel¹. Figure 1 shows diagrammatically the arrangement of its parts. Within the seed is the haustorial portion of the cotyledon, whose business it is to transfer to the shoot the stored material of the endosperm. Following it is a curious elongated body, the mesocotyl, which connects with the tubular sheath (coleoptile). All three parts (haustorial part of the cotyledon, mesocotyl and coleoptile) are regarded by Goebel as

¹ Goebel, K. *Organography of Plants*, II, 413, 1905.

collectively the cotyledon. Where the mesocotyl joins the coleoptile is the point of origin (within the coleoptile) of the leaves. In other words this is the site of the terminal bud. The mesocotyl is explained biologically as a means for facilitating boring through the earth by the coleoptile with its contained stem-bud. This adaptation is in itself a foreshadowing of the geophilous habit of which we shall have more to say later. The amount of elongation of the mesocotyl is to some extent determined by the depth of earth above the fruit. The radicle elongates and develops a few secondary roots. At this stage occasionally the fruit-coat shrivels, leaving the endosperm protected by the yellow seed-coat only. The junction of the mesocotyl and the coleoptile swells and adventitious roots start therefrom, the coleoptile itself bursts and the first true leaf emerges. After the development of two or three leaves and the growth of several adventitious roots the radicle darkens and shrivels. The contents of the seed remain attached to the seedling for a considerable time.

From the swollen base of the shoot (i.e., the swollen junction of mesocotyl and coleoptile), which we shall call the *basal bulb*, now appear one or more positively geotropic shoots which elongate and each forms a tuber at its end. (Plate I, 2.) These tubers launch out into vegetative growth of their own, but we shall leave their development for the present and concentrate our attention on the life history of the seedling thus far revealed.

5. *The Geophilous Habit.*

The salient point of this life history is the haste of the plant to form a tuber. This first tuber formation is completed within ten to fifteen days after germination. As an interpretation of this we cannot do better than refer to Miss E. Sargent's¹ brilliant paper "*A Theory of the Origin of the Monocotyledons founded on the Structure of their Seedlings*" and especially to that part of the paper which deals with the development of the geophilous habit. Miss Sargent deals specially with the correlation of the tuber-forming habit with the concrescence of the two cotyledons of the dicotyledon into the one of the monocotyledon, but from our point of view (that of mere adaptation to environment) her remarks are equally illuminating and we make no apology for quoting some of them.

"The formation of underground root-stocks, of tubers, corms, and bulbs, is characteristic of the plants called 'geophilous' by Professor Areschoug. The general definition of the term which he gives in part 1

¹ Sargent, Ethel. *A Theory of the Origin of Monocotyledons founded on the Structure of their Seedlings. Ann. Bot.*, XVII, I, 1903.

is very wide ; 'We include under that head such plants as form the buds by which they reproduce the shoot underground ; those plants in fact which develop their aerial organs more or less completely beneath the surface of the soil.' Defined in this way the term would include all biennials and herbaceous perennials of the temperate and arctic zones, for the aerial shoots of all such plants disappear during the winter, and are replaced in the following spring by the development of buds formed underground....

"In order to use the short season of vegetation to the best advantage the geophilous plant or geophyte must be furnished with a store of nourishment, and this is placed at some distance below the surface of the soil for protection against the cold or heat of the dead season. A plant so provided can throw up leaves and flowers at a few days' notice from the bud attached to its swollen axis or tuberous root.

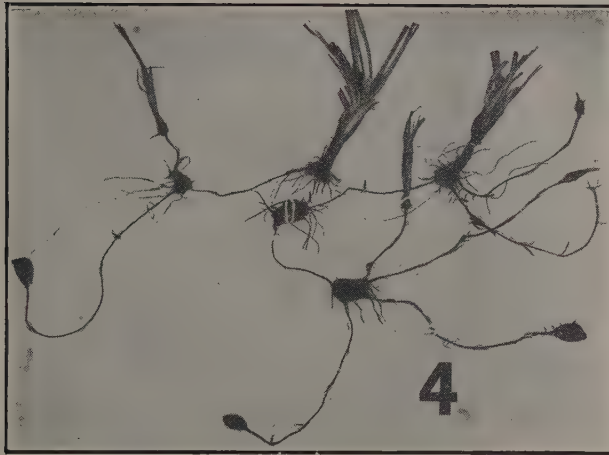
"The leaves when once above the ground make the most of their short life. They restock the underground organs with food for the following season, and they support the flowers, and later the maturing fruit, until the seed is ripe. When this occurs before the advent of the cold or drought withers the aerial shoots, the cycle of development is complete, but in such localities it must often happen that an early frost or a dry season kills all the seed formed by a plant before it is ripe.....

"When we consider the conditions under which a typical geophyte lives, it is very clear that its seedlings must be even more perfectly adapted to the environment than the mature plant in order to have a chance of surviving.

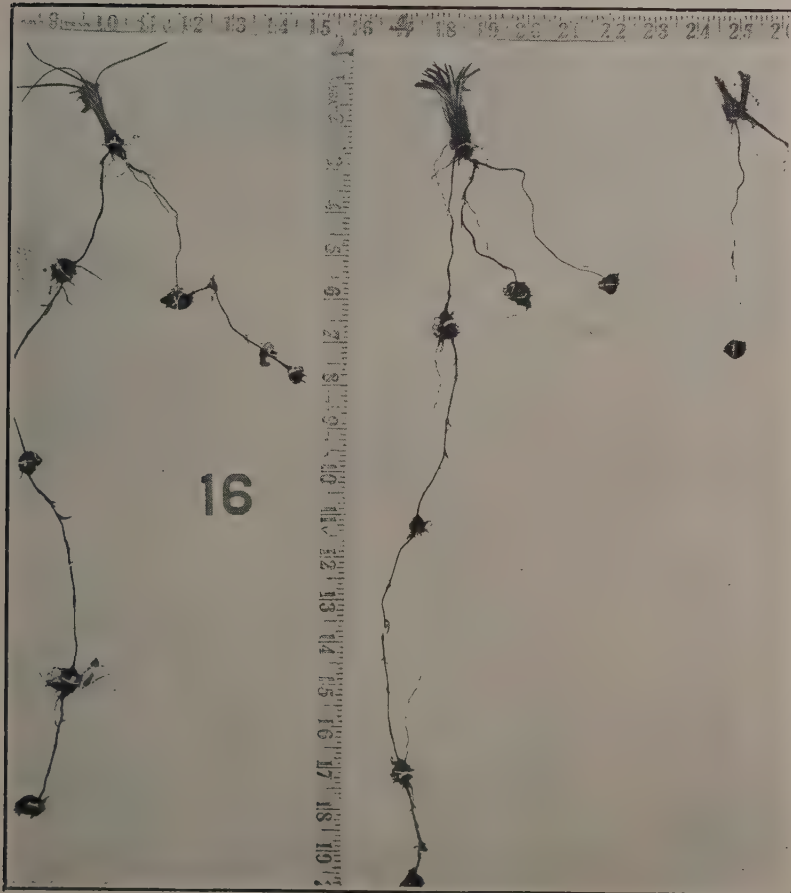
"The seed formed at the end of the growing period is commonly capable of resisting a considerable degree of cold or drought in the long dead season. When the genial weather returns and it germinates, the seed is confronted with a difficult problem. During the short period of vegetation the growth of the seedling must proceed in such a way that the structure completed by the end of the season is capable of living through the severe weather which follows.

"Accordingly we find that the seedling begins at once to form its underground organs.....

"In all these cases, however, the production of assimilating surfaces seems to be an object of secondary importance to the seedling of a geophilous plant in its first season. The formation of adequate subterranean organs at a safe distance below the surface of the soil is the condition on which the life of such a seedling ultimately depends, and its powers are devoted in the first place to this task."



1. Tubers giving rise to deeper tubers.



2. Typical droppers.

6. Other Tuber-forming Species.

Cyperus rotundus is not the only tuber-forming species. There are also *C. tuberosus*, and *C. esculentus* in the Bombay Presidency, and (so far as one can judge from plates and descriptions) *C. stoloniferus* elsewhere. *C. bulbosus* is not quite in the same class, since its tuber is more of the nature of a rosette of fleshy leaves. Of all the tuber-forming species, however, *C. rotundus* is easily first as to the depth and extent of its subterranean tuber-system, the beginning of which we have just been describing. It is, therefore, a plant which has developed the maximum amount of protection against drought, heat or cultivation. Little wonder that it has become one of the main weeds of the tropics and sub-tropics.

7. General Morphology and Physiology of the Tubers.

The tuber appears always to be the condensed end of an underground shoot. It consists of several short internodes, much swollen and bearing between them the scale leaves and buds of the nodes. The tuber is ovoid in shape and at its narrower end bears a terminal bud. The scale leaves of all the buds are deciduous. The tuber is at first externally white, but changes colour with age through red and brown to black. Each bud of a tuber can produce a rhizomatous shoot which either forms a tuber at its tip (and so on to form a chain of tubers with intercalated rhizomes) or else produces a rhizome that ends in an aerial shoot. The dormant apical bud can form only the latter.

The tubers are storehouses of food-material, mainly starch, and in addition are perennating organs buried at varying depths, admirably adapted to ensure the survival of at least some of their number.

We shall have, later in this memoir, to discuss at some length the formation and germination of these tubers, but we may for the present describe generally their behaviour.

After a plant has formed its first tuber it may form further rhizomes from a swelling (at the junction of the mesocotyl and coleoptile, henceforth to be called the *basal bulb*) and also from the tuber. There are two chief types of rhizomes those which are negatively and those which are positively geotropic. The positively geotropic shoots seek deeper layers and there usually form another tuber from which still another shoot going downwards may be formed. (Plate II, 1.) We thus find chains of tubers descending to considerable depths. We have provisionally called a rhizome which descends to some depth a "*dropper*". (Plates II, 2 and III, 1.) Any tuber whether on a dropper or not may form a negatively geotropic shoot which strives to reach

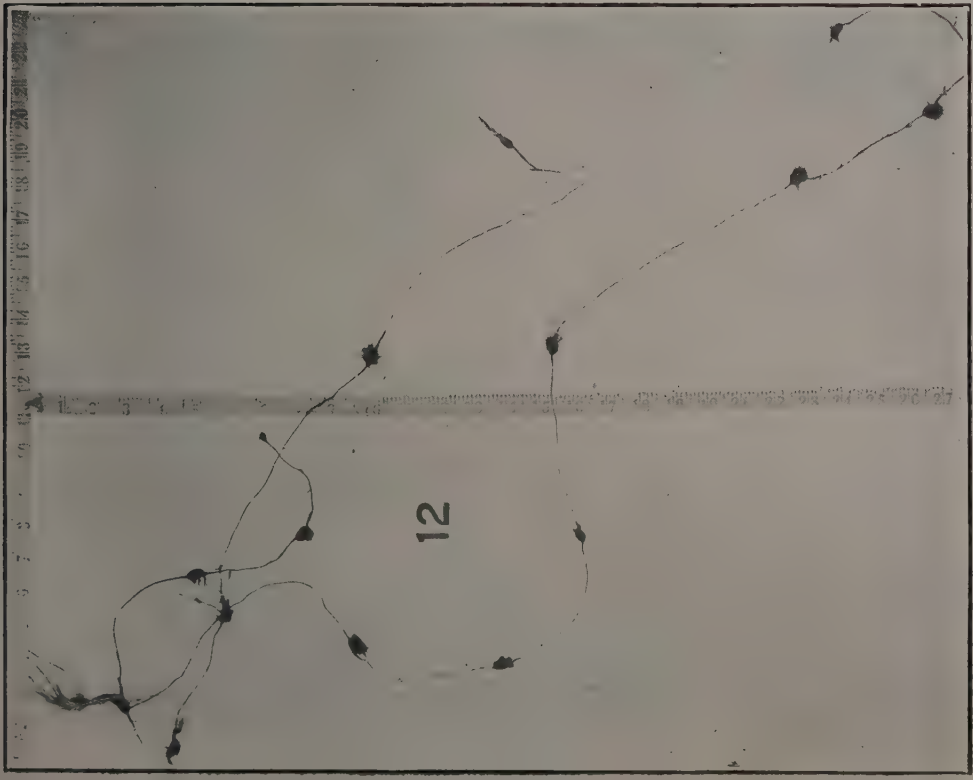
the light. If the tuber which forms this type of shoot is at a great depth then the shoot may have a considerable struggle to get to the surface and may possibly fail. In certain cases the plant resorts to the device of forming advanced bases in the form of intercalary tubers on the way up, into which it presumably sends its food material and so gets a fresh start from a higher level (Plate III, 2). In addition to rhizomes with a pronounced positive or negative geotropism there are also rhizomes which are more or less diageotropic and which spread in a horizontal direction either ending in tubers within the same soil layer, or eventually bending up or down.

The result of all these developments is the production underground of a large number of tubers at different depths, connected by rhizomes, and with certain rhizomes ascending to the surface and there producing the leaves which feed the tubers with starch. The number of shoots above ground is no indication of the number of tubers below ground.

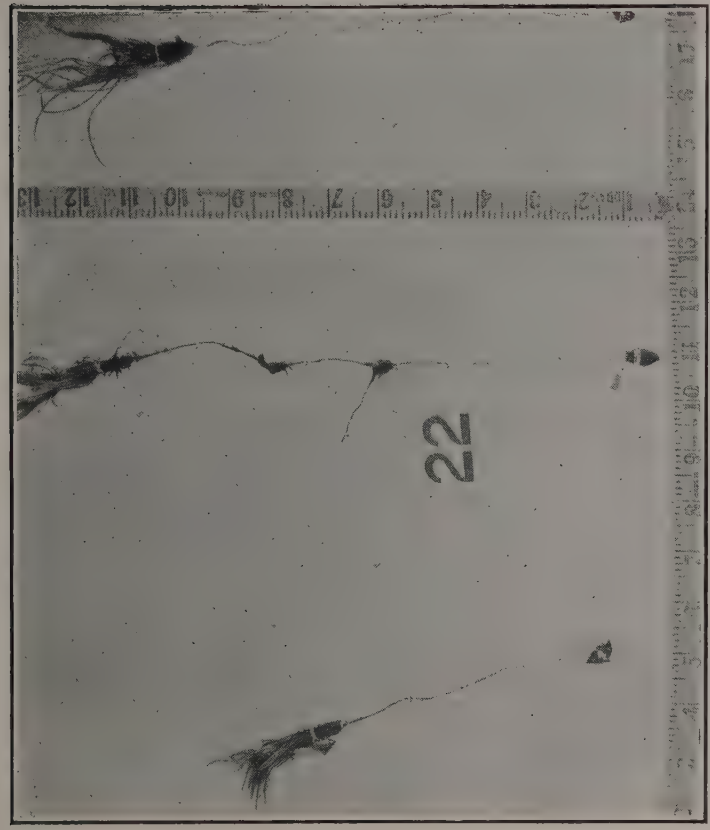
Put in another way this means that only a few of the tubers are actually in a state of growth. They are serving as food stores or exchanges but, unless some special stimulus is applied, they will not further burst into growth. Such a stimulus is the isolation of the tuber. In the various experiments recorded in detail later on, the effects of such planting of isolated and partially connected tubers are given.

At present we may draw attention only to one or two points in the germination of the tuber which are of interest. The isolated tuber, like the seed, makes its first business the establishment of an aerial connection. To this end, from one or more of its buds, it sends up a shoot which grows vertically and has considerable power of penetration even in hard soil. The apical bud is covered by white tough pointed scales forming a spearhead. On this bud reaching the surface the rhizome ceases to grow in length, the scale leaves which are exposed turn green and, instead of scale leaves, normal leaves are now developed. There is no further noticeable elongation of the axis until the formation of the inflorescence. At the junction of the normal leaves and the rhizome is formed a swelling apparently comparable to that which forms between the mesocotyl and the sheath of the seedling and from which, as in the seedling, shoots and roots may develop. We shall use the term *basal bulb* for this swelling also (Plate VI, 2). From the other buds of the tuber, after the establishment of the aerial connection, any kind of shoot may be formed, and, from the nodes of the tuber, roots may also develop.

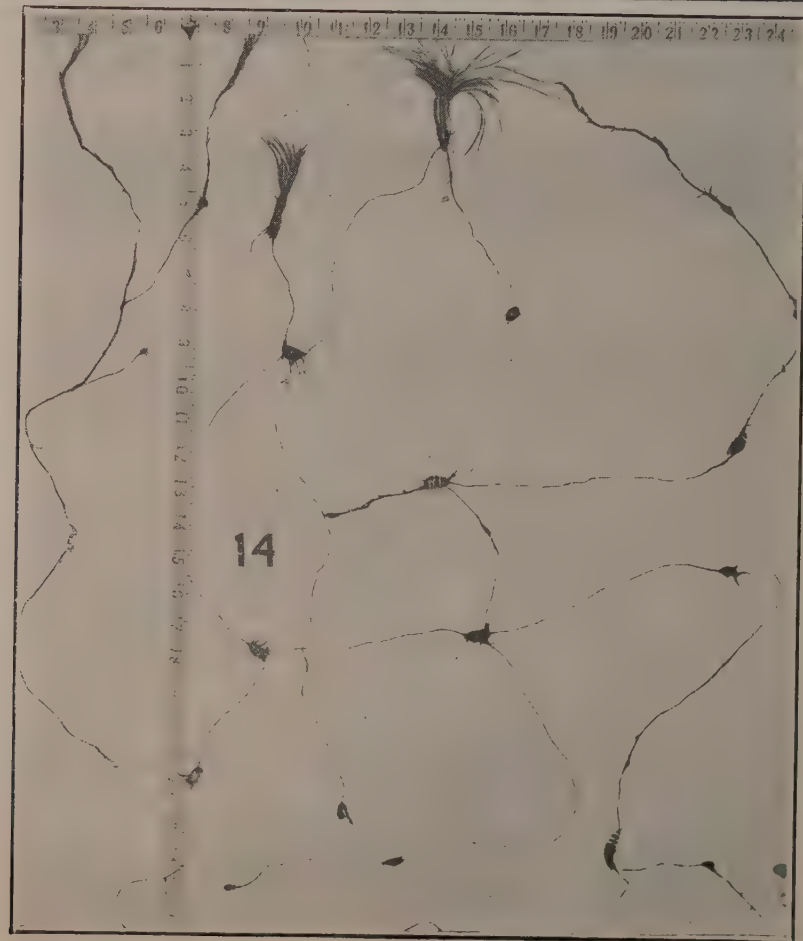
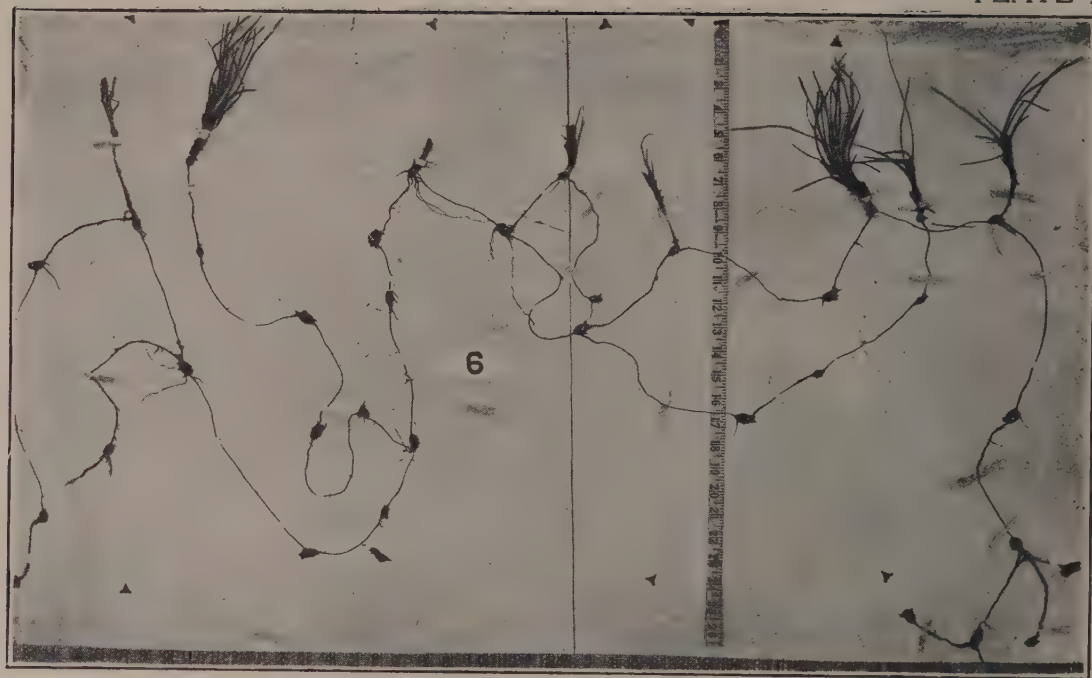
In superficially placed tubers most of the buds may develop to form shoots. In deeply placed tubers usually only one makes the attempt, the



1. Very long "droppers."



2. Growth of deeply planted tubers.



Characteristic Laval colonies.

tuber apparently concentrating all its powers in making one supreme attempt to get to the surface and not wasting material on several ascending organs.

Tubers may be cut or scraped without damage to their germinating powers.

We hope that the above details suffice to give a working idea of the structure of this plant, which is in reality a colony of tubers connected by rhizomes, distributed through a considerable depth of soil and fed by a comparatively small number of aerial shoots (Plate IV). Any tuber and, in fact, any bud of any tuber is a potential colony, and suffers not in the least by severance from its parent. The difficulties of eradicating such a plant already suggest themselves only too clearly.

8. *General Ecology of Cyperus rotundus L.*

Cyperus rotundus is essentially a weed of cultivation, and is specially to be found in irrigated fields. Outside cultivated areas it is rare, and seems to be unable to stand up to the competition of other vegetation. This characteristic is utilised by the Gujarat farmers who occasionally allow a very badly infested field to go fallow for several years continuously. The other vegetation (mainly grass in the later years) ousts the lavalala completely.

We have not had the time nor the opportunity to study the various stages in such a succession, but this is obviously a most interesting subject of research. We mention later some experiments on the effect of grass on lavalala. Lavalala does not grow in very salt land or in land which is inundated. On really salt land it is replaced by *Cyperus laevigatus* and on really marshy land by other Cyperaceæ. Its drought-resisting powers are considerable, but we consider these as more due to the disposition of its tubers than to any special xerophytic adaptations.

The lavalala plant in the Bombay Presidency flowers in July and August, (after the heavy rains of the first part of the monsoon), again in October and again in February and March. These are the times of general flowering, but flowering may occur at any time.

9. *The Anatomy of Cyperus rotundus L.*

Plowman¹ has dealt fully with the detailed anatomy of the whole order (Cyperaceæ), and there is little left to be described. Sabnis² gives anatomical

¹ Plowman, A. B. The Comparative Anatomy and Phylogeny of the Cyperaceæ. *Ann. Bot.* XX, 1906.

² Sabnis, T. S. The Physiological Anatomy of the Plants of the Indian Desert. *Jour. of Ind. Bot.*, II, pp. 167—173, 1921.

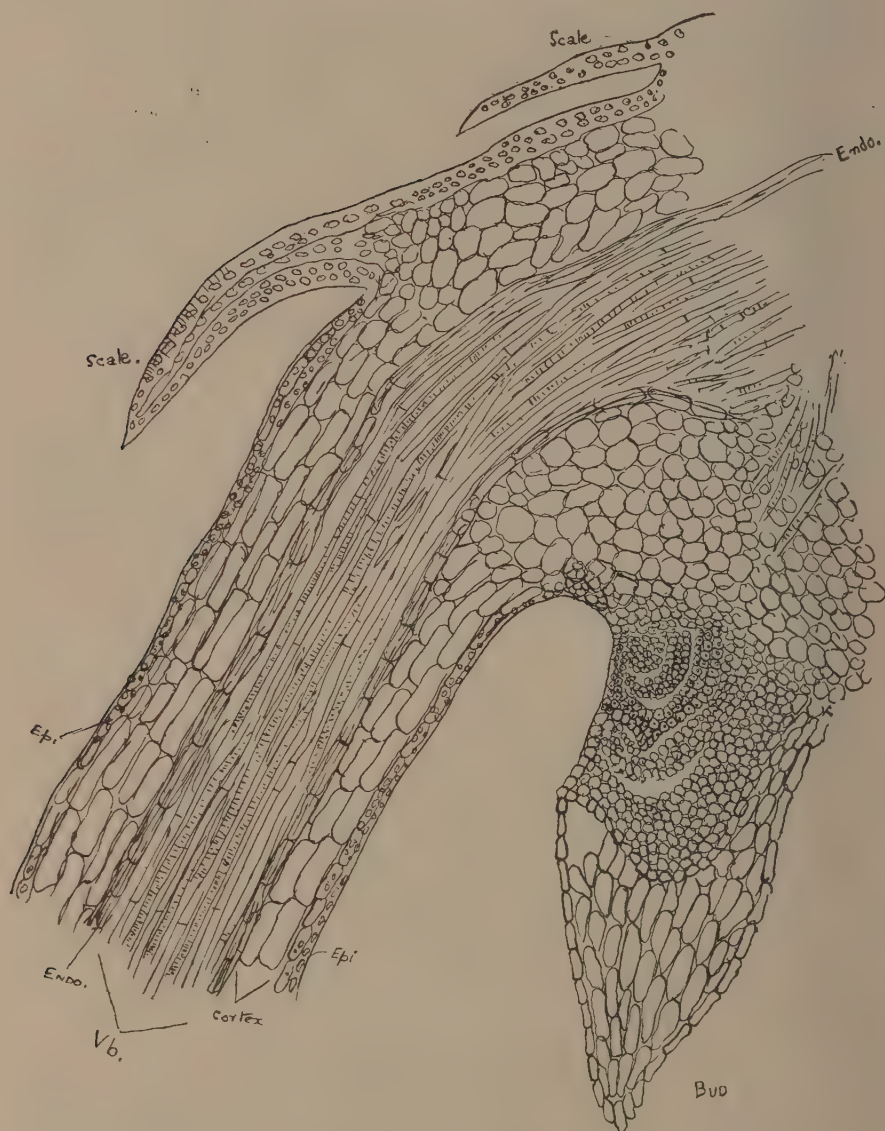


FIG. 2. Longitudinal Section of Rhizome and Tuber.

Vb=Vascular bundle.

Ep.=Epidermis.

Endo.=Endodermis.

descriptions and illustrations. From our point of view the most important organ for anatomical study is the tuber.

Tuber Anatomy:—

Fig. 2 shows the junction of a rhizome and a tuber. The rhizome is bounded externally by a much thickened epidermis. Within this is a starch containing cortex and a lignified endodermis. In old and wiry rhizomes the endodermis is the outer layer, the cortex and epidermis having disappeared. The endodermis is yellow in colour and contains a semi-viscid yellow fluid which does not give the reactions of tannin or suberin. The vascular bundles are normal and close set.

The epidermis of the tuber is slightly sclerenchymatous and may be of more than one layer. Arising from it and the immediately underlying tissues



FIG. 3.

Vb=Vascular bundle. Scl.=Sclerenchyma.

Ep.=Epidermis.

P=Palisade.

are the scale leaves. The bulk of the body of the tuber is a large-celled cortex and ground tissue containing starch in excess. The ground tissue

between the vascular bundles narrows down as the stele approaches the rhizome and is continued in the rhizome as elongated thin walled cells between the xylem vessels. The endodermis is continuous throughout tuber and rhizome. Roots originate from a rhizogenous procambium just within the endodermis. In the axil of each scale leaf is a bud and figure 2 shows one of these in section in a growing condition with a branch of the vascular system connecting it up with the main system of the tuber.

Scattered among the starch-containing cells of the ground tissue are isolated cells containing granular protoplasmic sacs. Small refractive granules in these sacs are dissolved in ether. The substance appears to be of the nature of an essential oil or a resin.

In cuts on the surface of tubers we find a copious exudation of gum, accompanied with degeneration of starch in the cells abutting on the cut.

Tubers exposed to the sun and dried have almost empty cells in the cortex and ground tissue. Such starch grains as are found are yellowish in colour and reduced in size.

Tubers exposed for a long time to the sun or exhausted by continued removal of the aerial shoots are reduced to the sclerenchymatous endodermis and the lignified elements of the stele.

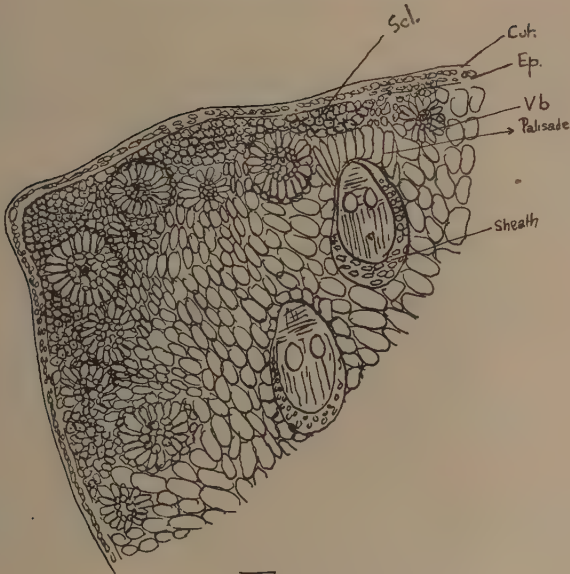
Leaf Anatomy :—

The leaf has a strikingly large-celled cutinised upper epidermis which probably functions as a water storage tissue. The lower epidermis is insignificant. There are no stomata in the upper epidermis. On the lower epidermis the stomata are found between the sclerenchymatous sheaths that accompany the vascular bundles. The stomata are present in the density of from 140 to 370 per square millimeter in different parts of the leaf. The assimilating tissue is that round the vascular bundles. In other words the bundle sheaths are also the assimilating cells.

The leaf is on the whole of a xerophytic type.

Rachis of Inflorescence.

Fig. 4 shows this in cross section. There is again a markedly cutinised epidermis. The superficial vascular bundles have an assimilating bundle sheath like those in the leaves. The deeper lying bundles are larger and of normal structure with sclerenchymatous sheaths. The ground tissue is parenchymatous.



Transverse section
— of RACHIS —

FIG. 4.

Cut. = Cuticle.

Ep. = Epidermis.

Scl. = Sclerenchyma.

III. EXPERIMENTS IN THE PROPAGATION OF *Cyperus rotundus* BY SEED.

It was necessary to find out as accurately as possible how effectively *Cyperus rotundus* propagates itself by means of seed. In December 1921 the number of seeds produced per inflorescence was determined for one hundred inflorescences. One cannot with ease determine the number of seeds *per plant* because, as we have seen, a plant is a colony of varying size and of limits difficult to define. The numbers found were as follows :—

Class					Frequency
No. of seeds per inflorescence					
1—100	..	..	..	..	16
101—200	..	..	..	..	39
201—300	..	..	..	..	23
301—400	..	..	..	..	14
401—500	..	..	..	..	6
501—600	..	..	..	..	1
601—700	..	..	..	..	1

The mean number of seeds per inflorescence is 220. The nature of the distribution is that of a skew frequency curve with the mode near the lower limit. The wide range of variation (actually from 10 to 607 seeds per inflorescence) is presumably an indication of the wide range of conditions in which the plants lived.

Taking fifty inflorescences per square yard (a quite moderate figure in an infested field) this would mean the production of 11,000 seeds per square yard or 53,900,000 seeds per acre, and that probably three times in the year. If all these seeds are viable, we have here a very effective means of propagation.

The first tests of viability were made in 1920. The seeds were placed in porcelain dishes on damp sand in a germinating box. From June 1920 till February 1921 these tests were repeated, but no germination resulted. We have not been able to determine the reason for this failure to germinate, unless it be that the seeds were not in contact with the sand, but only with the moist porcelain.

The next tests were made in April 1921 with seeds collected in October-December 1920. These seeds were variously treated before being put to germinate. The treatments given being—

1. Control . . . no treatment.
2. Exposure daily to the sun for a month.
3. Heating for three hours continuously at 124°F. (51°C.) in an oven, and cooling slowly.
4. Heating as in (3) and cooling rapidly.
5. Soaking the seeds in hot hydrochloric acid of ten per cent. strength for half an hour.
6. Puncturing the seed coat by a needle.

Fifty seeds were treated in each batch and were then put to germinate, twenty-five (of each fifty) in pots in the open and twenty-five in wet sand in petri dishes in a moist chamber in the laboratory. The seeds in the pots were sown one inch below the surface and the soil was watered daily. The air shade temperature maximum was 94°F. (34°C.) and the moist chamber temperature maximum 84°F. (29°C.). In the pots there was no germination visible in ten days (April 1st to 10th), but in the petri dishes germination occurred as follows:—

Treatment	Germination
1	5
2	8
3	18
4	10
5	8
6	8

TABLE I.

Germination of seeds of Laval.

Experiment to determine the effect of heat and rest. Heating was done in an oven at 139°F. (95°C.) for one hour.

No. of seeds in each test, 25.

Time :—12th to 30th April, 1921.

No.	Process	In pots—soil 3" deep, seeds 1" below the surface. Watered daily	IN MOIST CHAMBER IN PETRI DISHES ON MOIST SAND		REMARKS
			Germinated seeds	Percentage	
I.	<i>Fresh seeds—</i>	None of these			
	1. Unheated..	germinated	6	24	Seeds germinated in the conditions of the moist chamber. Heating apparently helps germination.
	2. Heated ..	though watered	16	64	
II.	<i>Rest of one month—</i>	daily, till the			
	1. Unheated..	end of July	8	32	
	2. Heated ..	but all germinated in the	17	68	
III.	<i>Rest of two months—</i>	rainy week	5	25	
	1. Unheated..				
	2. Heated ..	21st-31st July, 1921	15	60	
IV.	<i>Rest of four months—</i>	No record kept for number.			
	1. Unheated..		20	80	
	2. Heated ..				

It will be noticed that the seeds heated in the oven germinated better than the others, treatment 3 giving a 72 per cent. germination.

Another experiment, the method and results of which are recorded in Table I, was carried out from April 12th to 30th, 1921. The following interesting points emerge—

- (1) The heated seeds germinated better than the unheated.
- (2) The long rest apparently helped the germination of the seed.

Simultaneously with this experiment in petri dishes a duplicate set was sown in pots, but these did not germinate until the very rainy period of July 21st to 31st, 1921. The fact of their germination was then noted but no counts were made. These pots were watered daily but only the actual rains stimulated their germination.

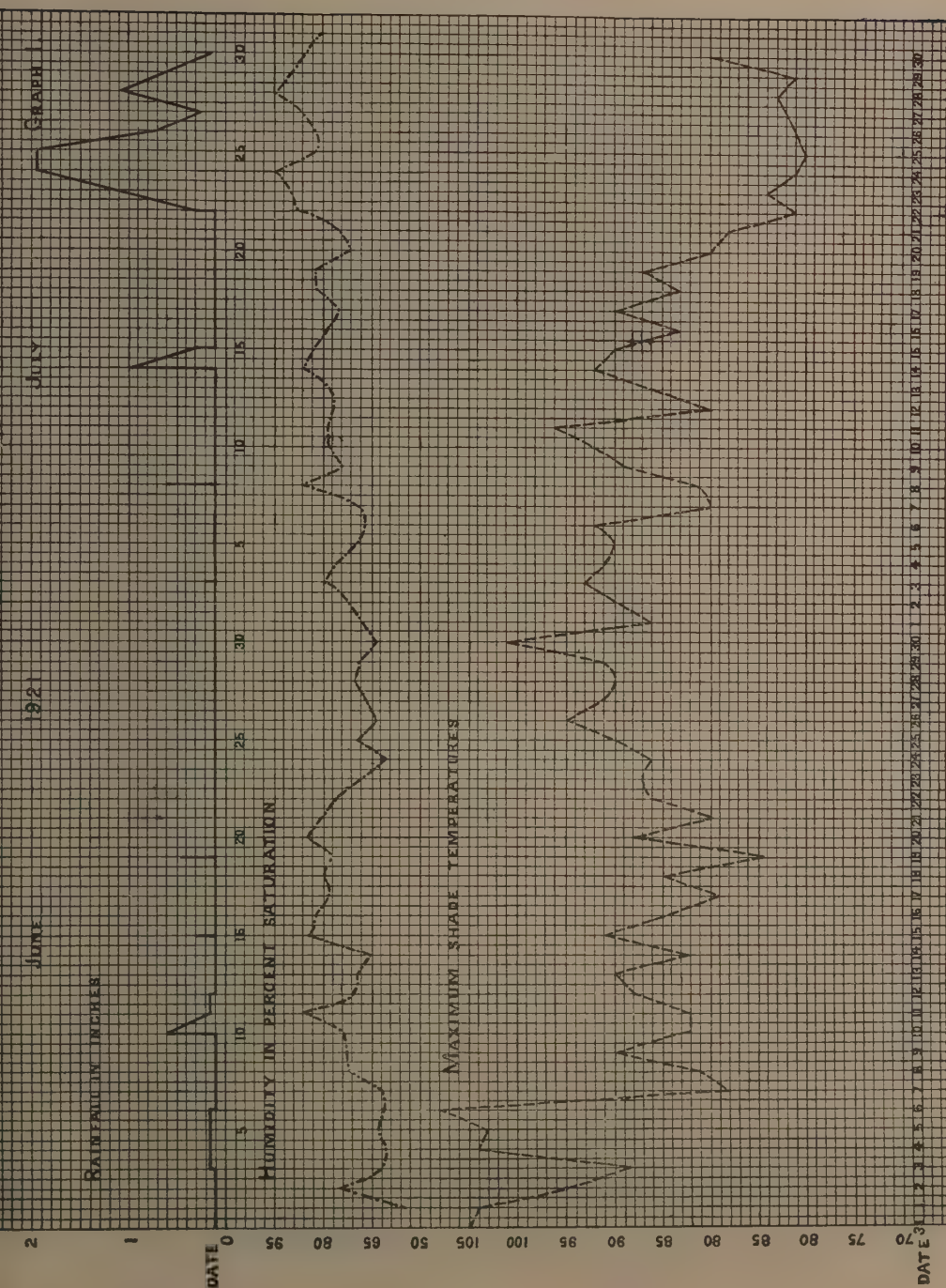
In another experiment seeds collected on March 2nd, 1921, were sown at once in pots. One pot was placed out in the sun and the other in the veranda sheltered both from rain and direct sunshine. The pot in the open was not watered, and that in the veranda was watered twice a week. In *neither* pot was there any germination until July 23rd, when germination began in both pots. Graph 1 shows the rainfall, humidity and maximum shade temperature at the time of these two last mentioned experiments.

In December, 1921, the seeds from 100 inflorescences were sown in pots, one pot being devoted to the seeds of each inflorescence. These pots were not watered and were kept in the open. Germination began on July 4th, 1922. Graph 2 shows the rainfall, humidity and shade temperature at the time. During this period there was also copious germination of lavalva seeds in the fields. The total number of seeds sown in this experiment was 22,086, but the average germination was only 1.5 per cent. The greatest percentage of germination from any single inflorescence was 8 per cent. Many of these seedlings withered.

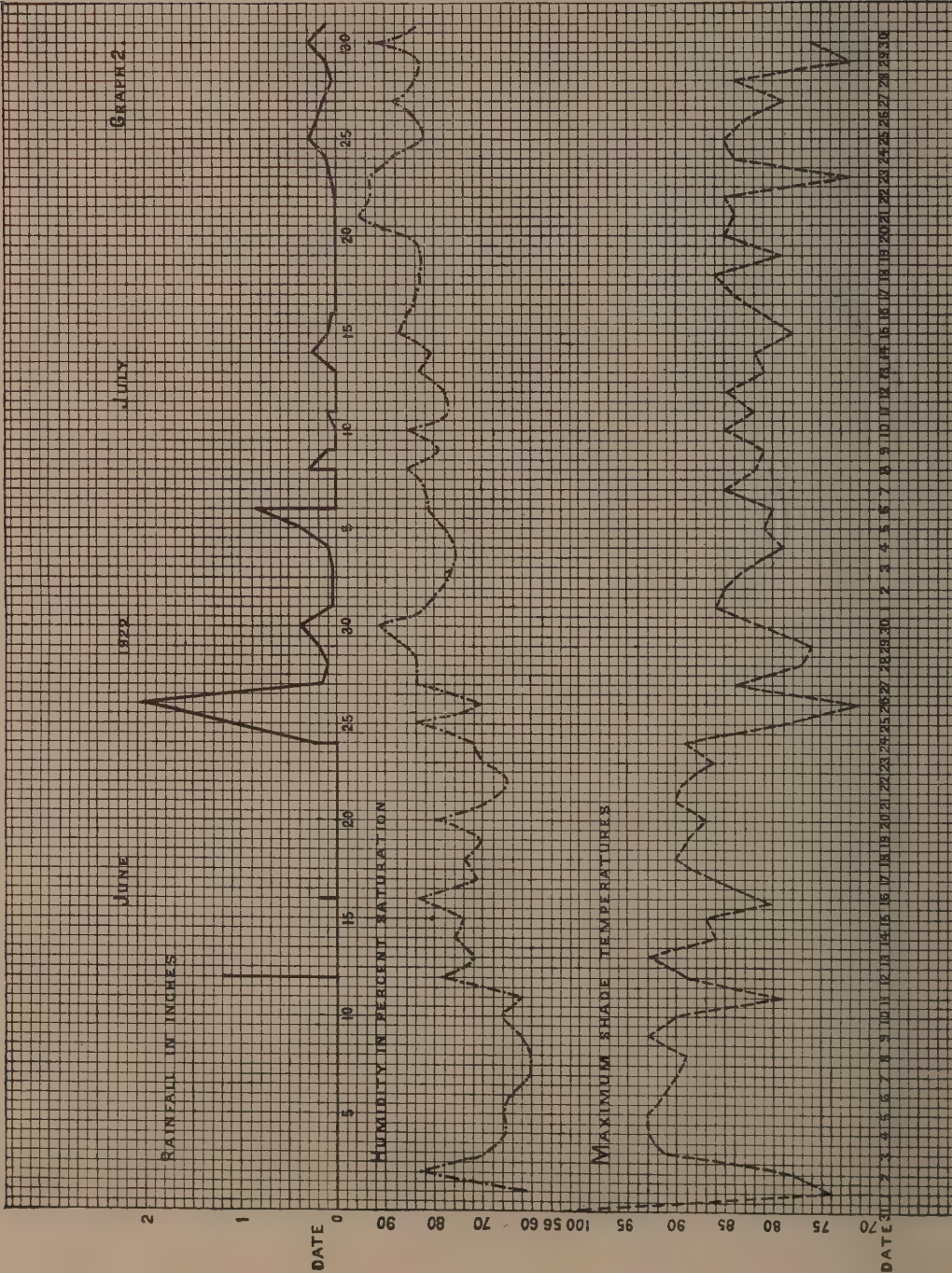
In November, 1922, there were unusual rains (Graph 3). During this period further germination took place in the above pots containing the seed of the 100 inflorescences. No exact counts were made, the amount of germination being small. Observation of germination in the field during the monsoon of 1923 generally corroborated the 1921-1922 observations.

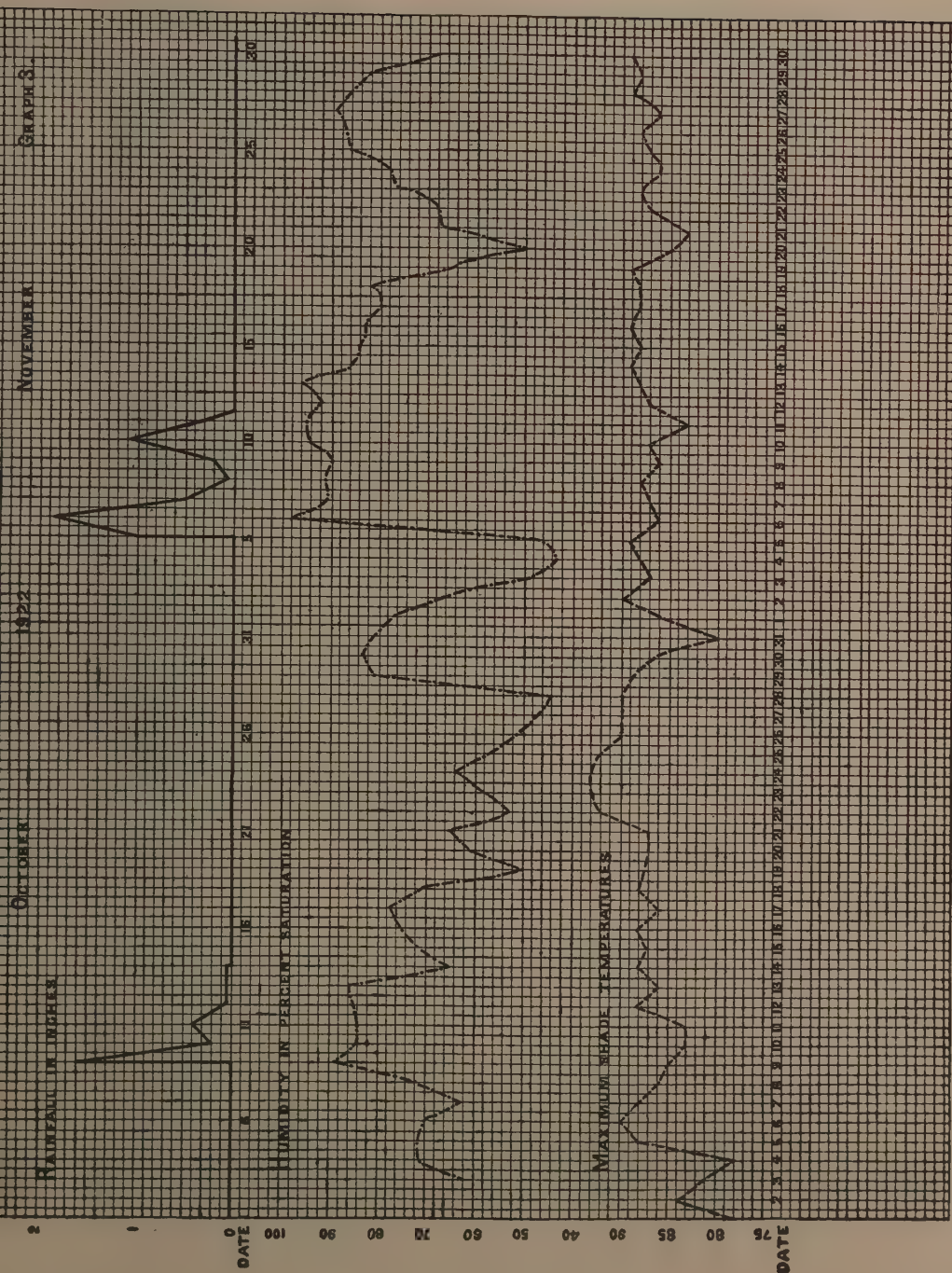
The above experiments lead us to the following conclusions :—

- (1) Soil moisture without atmospheric humidity will not cause germination.
- (2) In the field the rainy season is therefore the only one when much germination of seeds will occur.
- (3) Even in the rains the actual germination percentage is low, and many seedlings die.
- (4) Propagation by seeds is not therefore the main method of propagation, but on account of the enormous total amount of seeds produced per acre, this method of propagation cannot be overlooked and must be checked by methods designed to eradicate this weed before it sets seed.



GRAPH 1.





GRAPH 3.

IV. EXPERIMENTS IN THE PROPAGATION OF *Cyperus rotundus* BY TUBERS.

Recognising that tuber-propagation is the main method by which this weed spreads itself, we made a large number of experiments of various kinds on the germination of the tubers and the after-growth of the shoots developed from germinated tubers. The general behaviour of the tuber in germination and of the shoots in after-growth have already been briefly described. Our experiments were designed to get the maximum amount of information regarding the life-cycle.

The experiments may be briefly classified as—

- (1) Experiments in the germination of isolated tubers,
 - (a) of different ages,
 - (b) dormant or sprouting,
 - (c) at different depths in the soil.
- (2) Comparison of the germination of isolated and connected tubers.

Experiment I.

On June 10th, 1920, five black dormant tubers and five white (fresh) dormant tubers were placed in a shallow dish with a little water. This dish was not covered and was kept in the laboratory. In five days all the tubers had slightly increased in size due to water absorption. The buds also were slightly swollen. During the next five days buds elongated to form green shoots. In all the fresh tubers and in all the black tubers in which the apical bud had not previously germinated, the apical bud was the first to sprout. Thereafter the other buds sprouted in acropetal succession. The buds are conical and covered with pointed scale leaves. After the true leaves began to form adventitious roots arose from the base of the buds.

Experiment II.

On July 15th, 1920, ten dormant tubers were placed on top of moist sand exposed to light and ten were planted, one to three inches deep in moist sand. Those on top behaved like the ones described in Experiment I, except that root production was more copious. All buds including those on the under side of the tubers produced shoots which were markedly negatively geotropic.

Shoots from the tubers buried one inch deep appeared on the surface on July 20th. The more deeply buried ones showed shoots above the surface on July 25th. In all but two tubers only one bud had sprouted, this bud being

either the apical bud or the one next to it. In two tubers two buds sprouted simultaneously. Root formation from the tuber nodes was copious. The formation of the vertically growing rhizome between the tuber and the tuft of leaves, and the development of the swelling (basal bulb) at the base of the tuft were first observed in this experiment.

On July 25th, all ten buried tubers were dug out for examination, and five of these were replanted in sand and five in black soil on the same date. At this stage, in addition to the vertically growing rhizome ending in the tuft of leaves, some tubers had developed other rhizomes one or two inches long and certain of these were positively geotropic. At the time of replanting, these tubers were deliberately put in upside down. On August 10th, the plants were again dug out and re-examined. Some of the reversed rhizomes had once more turned down and some had not. Those which had turned down had each formed at their ends a white tuber covered with fibrous scales. The others had formed shoots on the surface. The plants in the black soil had leaves larger and of deeper green than those in the sand. All plants were replaced in the sand or soil and left undisturbed until December 10th, 1920, when they were finally dug out. During their life-time they had been watered twice a week. Flowering took place in the second week of August. It is possible that the transplanting may have accelerated the flowering. All shoots in the sandy soil flowered, but only two in the black soil. In both soils, although watered, the aerial shoots died in September and October. In the second week of November the dormant tubers (both new and old), as also the aerial parts, began to sprout.

When the plants were finally dug out the five tubers in the sand had increased to twenty and the five in the black soil to fifty. Those in the sand were more closely set than those in the black soil.

Experiment III.

In a piece of unirrigated land on the College Farm, 300 dormant isolated tubers were planted in three lots of 100 each at three inches deep, with intervals of four inches each way, on August 10th, 1920. The tubers were not artificially watered but received 10.38 inches of rain during the experiment. Shoots appeared above ground from September 3rd, 1920. Some of these flowered and all began to wither by the beginning of December. The plants were removed carefully and studied for the sequence of tuber formation. Much of the morphological information recorded on page 109 was obtained from this planting.

Experiment IV.

On September 13th, 1920, a set of 100 dormant isolated tubers was planted at 6 inches deep and 4 inches interval in a plot similar to that of Experiment III. These received rainfall of 9.94 inches. Aerial shoots appeared from October 15th. The greater time for the appearance of these is probably caused by the greater depth of planting. The plants were dug out on March 21st, 1921. All aerial parts had by that time withered. Some tubers had remained dormant. Those which germinated had all first produced the upward-growing rhizome ending in the leaves and thereafter tuber-forming rhizomes both from other buds of the original tuber and from the basal bulb. From both these places roots were also developed. One or two of the original tubers had become exposed and in their case all the buds sprouted to form shoots, without any downward-going rhizomes.

These preliminary experiments give the following indications :—

- (1) All buds on a tuber have the power of germination. In exposed tubers all these may germinate and produce shoots. In buried tubers the apical one if present, if not, the next, and in some cases both, may germinate to produce the vertically growing rhizome ending in the tuft of leaves. In some cases the tuber may not germinate but remain dormant.
- (2) The time between the planting of the tuber and the appearance of the shoot above the soil is determined by the depth of planting of the tuber.
- (3) The time between the planting of a tuber and flowering may be in the case of the transplanted plants as short as one month. In the field up to two and a half months may elapse between planting a tuber and flowering.
- (4) The rate of increase of tubers is considerable even in the unfavourable conditions of the plants which were dug out to see how they were getting on. Plants in good soil develop longer rhizomes and more tubers than those in poor soil.

Experiment V.

Twelve big robust dormant tubers were planted 3 inches deep in pots in ordinary soil on June 15th, 1921, and finally dug out on August 29th, 1921. Between these dates they were dug out once a week to observe development and Table II shows the results.

TABLE II.

Experiment V.

To study tuber development.

Tubers planted on June 15th, 1921. Plants dug out on August 29th, 1921.

Label No.	Germination of original tuber	Inception of the first new tuber	Sprouting of the first new tuber	Formation of second new tuber	REMARKS
65	20-6-21	1-8-21	13-8-21	5-8-21	
66	"	29-6-21	1-8-21	1-8-21	
67	"	24-6-21	29-6-21	29-6-21 to 1-8-21	
68	"	29-6-21	20-7-21	5-8-21	
69	"	20-7-21 (tip broken, so no tuber) 1-8-21	5-8-21	13-8-21	
70	27-6-21	20-7-21	1-8-21	"	
71	20-6-21	5-7-21	20-8-21	20-8-21	
72	"	20-6-21 (dead) 1-8-21	13-8-21	13-8-21	Flowered 20-7-21
73	"	20-7-21	No shoot	"	Flowered 5-8-21.
		From basal bulb 1-8-21 From tuber			
74	"	29-6-21	1-8-21 (Sprouted with a tuberous swelling near the side of the pot)	5-8-21 (2 tubers, one sprouted)	
75	24-6-21	"	25-7-21 (2 white shoots one with a sprouting tuberous swelling)	10-8-21 (the disconnected tuber produced one downward branch)	
76	"	1-8-21 (dried)		12-8-21 (New tuber from parent tuber)	

The following facts appear:—

- (1) Out of the twelve tubers nine germinated within five days of planting and the average time was 6·25 days.
- (2) Two plants flowered 35 and 51 days respectively after flowering.
- (3) The average time for the inception of the first new tuber was 22·4 days.
- (4) The average time after the inception of this tuber for it to sprout was 23·5 days.

It will be particularly observed that there was little pause between the formation of a tuber and its further germination. This fact was confirmed by further pot experiments in which isolated white newly formed tubers were planted and germinated immediately, giving plants more vigorous in growth than those from old black tubers.

Experiment VI.

A. An experiment in planting chains of tubers in pots.

Twelve pots were filled with earth and a small chain of three connected tubers planted in each. Four chains were planted horizontally, four vertically with the youngest tuber upward, and four diagonally across the pot of which two had the oldest tuber uppermost and two had the youngest tuber uppermost.

In the horizontally placed chains the oldest tuber sprouted first. In the vertically placed chains the upper one sprouted first, the lowest remaining dormant or sprouting late. In those placed diagonally the two end tubers sprouted before the middle one. The position in the chain and the depth of planting seem to have therefore some effect on the germination.

B. A similar experiment was started in the field with longer chains of tubers, planted so that the tubers were from 3 to 9 inches below the surface, and any existing aerial shoots in their normal position. These aerial shoots withered, and new shoots replaced them. Planting was done from September 25th to October 2nd, 1920. The rainfall during the experiment was 8·30 inches. The new shoots finally withered in February 1921. An attempt was made to keep a record of the appearance of these shoots, but the record soon became unmanageable. On digging out the plants, however, some useful information was obtained, of which the following notes are given.

(1) Replacement of the aerial parts after withering.

The withering of the leaves may or may not mean the death of the terminal growing point. If this remains alive then when conditions are favourable it

may continue the formation of leaves as before. In addition, since the actual attachment of the aerial leaves to their stem is somewhat below the soil, there may arise new shoots from the primordia in the axils of these leaves and such may develop before the terminal growing point renews its growth, or in the event of its death. Each such new shoot develops its own basal bulb.

New shoots may be formed by the production of a rhizome from the basal bulb or from the vertically growing rhizome below the basal bulb whose leaves have died. These rhizomes make for the surface and there develop new leaves. The point of origin of such a new rhizome from the vertical rhizome of the original plant is sometimes marked by a swelling like an incipient tuber.

(2) Water supply of the aerial parts.

Adventitious roots are developed, as we have seen, from the basal bulb and also from the rhizome and tuber nodes. One case, however, was found in this experiment when there were no roots from the basal bulb and the aerial parts were apparently getting all their moisture from the roots of the tuber one foot below the surface. This is probably a normal occurrence when the surface soil dries out.

(3) Effect of cracks in the soil.

The vertically growing rhizome normally drives its way to the surface and there produces leaves. In very cracked soil if a vertical rhizome pierces a crack the stimulus of the light causes the leaves there to develop, but somewhat faultily, so that they emerge from the soil in a curiously twisted manner.

(4) Two curiosities.

- (a) One of these was a plant which had sent to the surface the normal vertical rhizome, and this had there formed shallowly placed tubers close together in quick succession, all of them showing traces of aerial leaves.
- (b) The other was a tuber which bore ten old leaves when planted. This tuber produced one more tuber which in turn developed one aerial shoot and *six* droppers.

1. *Experiments in Deep Planting of Tubers.*

From indications got in this and previous experiments it was decided to make a thorough test of the effect of depth of planting on tubers. These experiments are now recorded.

Experiment VII.

An experiment in the planting of tubers at various depths.

Three rows were arranged each containing eight plots, each three feet square, and in each square plot were planted ten old dormant isolated tubers.

Those in the first row were planted 2 ft., those in the second row $2\frac{1}{2}$ ft. and those in the third row 3 ft. below the surface. The rainfall during the period of the experiment was 8.30 inches. Table III shows the main results of the experiment as revealed when the plants arising from these tubers were dug out on the dates mentioned.

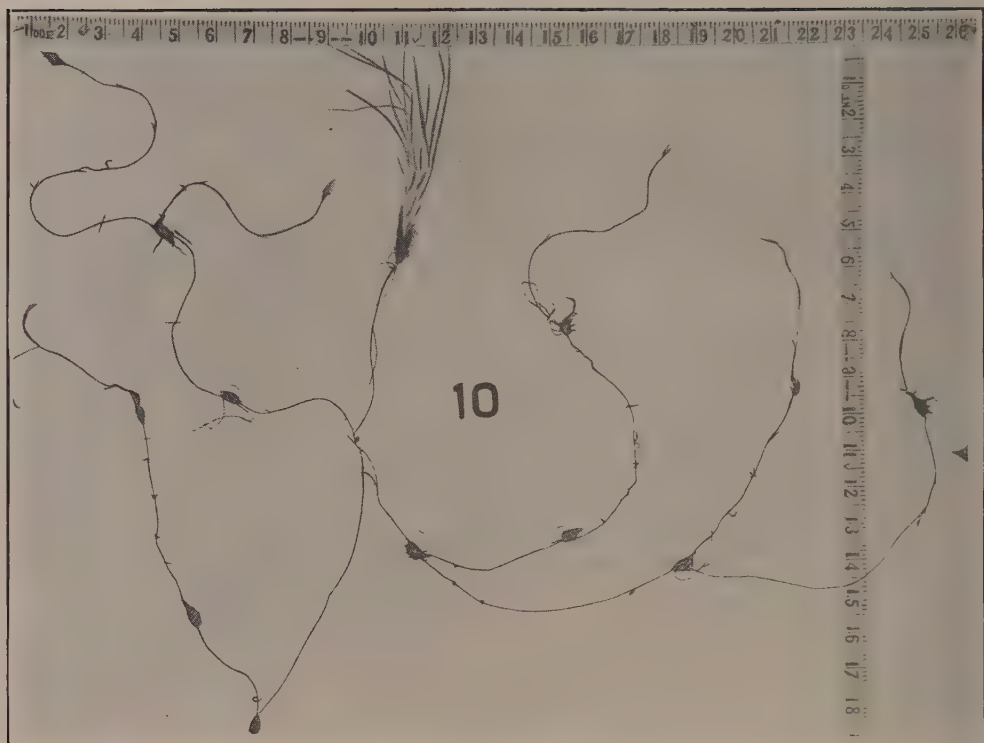
The most salient fact in this experiment is that none of the tubers at 3 ft. deep were able to send their shoots to the surface. Of the 80 tubers in this series only 2 were living at the end of the experiment, 32 were recognisable but empty and shrivelled, and the others (of which shreds were found) had so disintegrated as to be unrecognisable.

The next noticeable point is the marked disadvantage of the plants at $2\frac{1}{2}$ ft. as compared with those at 2 ft. This is clearly shown in the smaller number of tubers in the upper three inches, still more in the smaller number in the middle layers, and also in the smaller number of aerial shoots.

TABLE III.

Planting to the depths 24 and 30 inches on October 5th, 1920. Percentage of germination and density at various depths. (10 tubers in each square).

Row No.	Sq. No.	Depth of planting (20 tubers)	Date of planting	Dug out on	ORIGINAL TUBERS		Shoots on the surface	Total number of tubers in the first 3 inches
					Living	Sprouting		
I.	1	2 feet	5-10-20	5-7-21	1	1	10	6
	2	"	"	"	4	4	10	15
	3	"	7-10-20	7-7-21	2	2	5	7
	4	"	"	8-7-21	1	1	6	8
	5	"	"	9-7-21	4	4	5	10
	6	"	"	10-7-21	5	5	5	5
	7	"	"	"	5	5	5	10
	8	"	"	11-7-21	4	4	10	13



Two rhizomes take off directly from the middle vertically growing rhizome.

TABLE III—*contd.*

Row No.	Sq. No.	Depth of planting (20 tubers)	Date of planting	Dug out on	ORIGINAL TUBERS		Shoots on the surface	Total number of tubers in the first 3 inches
					Living	Sprouting		
II.	1	2½ feet	7-10-20	12-5-21	4	2	2	3
	2	"	"	15-5-21	5	2	3	2 near the surface
	3	"	"	1-6-21	2	2	2	3 (2 basal swellings and 1 tuber)
	4	"	"	"	2	2	2	3 (1 new tuber which soon died)
	5	"	"	5-6-21	4	4	4	4 (Basal swellings)
	6	"	"	7-5-21	6	2	4	2 basal swellings and 3 new tubers
	7	"	"	13-4-21	8	8	4	4 (Basal swellings)
	8	"	"	3-5-21	4	10	4	4 (Basal swellings)
III.	1	3 feet	9-10-20	14-5-21	8	1	..	No tubers in first three inches in any case and no shoots on surface.
	2	"	"	"	6	..	..	
	3	"	"	16-5-21	1	1	..	
	4	"	"	20-5-21	1	..	..	
	5	"	"	"	3	..	..	
	6	"	"	13-5-21	9	..	..	
	7	"	"	12-5-21	7	1	..	
	8	"	"	10-5-21	5	..	..	

The following general observations arise from a study of the 2 ft. and 2½ ft. plantings.

(a) The same three points of origin of tubers, as previously observed, were again in evidence, viz.

(i) tubers might arise from rhizomes originating from the basal bulb.

(ii) tubers might arise from rhizomes originating directly from the vertically growing rhizome. (Plate IV.) In most cases such secondary rhizomes took off in the top three inches of soil.

In both cases these rhizomes might grow definitely downward from the start, when they would be classed as droppers, but the rhizomes taking off directly from the vertically growing rhizome often grew horizontally. (Plate V.)

(b) Once the originally planted tuber had established its aerial connection it did not produce further shoots and left the production of new aerial parts to the younger portions of the colony.

(c) In one case a tuber planted at $2\frac{1}{2}$ ft. showed swellings, apparently incipient tubers, on the vertical rhizome.

(d) Tubers, which either did not germinate or which had germinated and whose shoots had not reached the air, were either shrivelled and devoid of starch or dead although plump. The viability of these later was tested by re-sowing them in pots at a shallow depth and watering them. They did not germinate. When sown they possessed starch but two months later none could be recognised. Later experiments indicate that if the original buds of the tuber are destroyed, adventitious buds are not formed and the tuber, though plump, does not germinate.

It is obvious that such important indications as those given by the series of experiments just described had to be confirmed, and hence further experiments were laid out. These are now described in detail.

Experiment VIII.

On December 4th, 1920, a pit 3×3 ft. was dug out to determine the number of tubers per cubic unit of soil. At the time of refilling of the pit 28 old dormant tubers were placed at the bottom of the pit and earth, free of tubers, filled in on top. The pit was again dug out on April 13th, 1921. No shoots had up to then appeared on the surface. There had been slight rains on January 15th and 16th and thunderstorms on April 3rd and 12th. The soil up to three inches deep was wet, then the layer up to $2\frac{1}{2}$ ft. was dry and the last layer wherein lay the tubers was wet with a capillary moisture content of ten per cent. (calculated on the wet weight). Most of the tubers had produced upward growing rhizomes in an attempt to reach the surface. In seven cases these rhizomes showed tuberous swellings with developing buds, and in two cases typical tubers (not mere swellings) were produced. After an hour the tubers and their growths were returned to the pit and the earth filled in again. The pit was dug out for the second time on August 13th, 1921, after a total rainfall of 11.52 inches since the first excavation. No shoot had appeared on the surface, and all tubers, both the original ones and those formed later, had died.

The following observations were made:—

(a) Again the tubers planted three feet deep did not succeed in reaching the surface. In the present case their attempt was interrupted by the first digging.

(b) Again the terminal bud of the tuber sprouted to form the upward-growing rhizome. Other buds had sprouted later, possibly stimulated by the check to the first formed rhizome. No descending rhizomes were formed.

(c) From this and other experiments we think we are safe in stating that a tuber does not produce a descending rhizome until it has established its aerial connections.

(d) Where the growth of the apical bud of the vertical rhizome had been hindered by some hard object there was a tendency towards tuber formation at the part in contact.

(e) In growing through hard dry soil the vertical rhizome had a twisted appearance.

(f) The younger parts of the vertical rhizome were anatomically complete, but the older parts were bounded by the endodermis, all parts external to it having decayed.

Experiment IX.

This was conducted as follows:—

The soil of the plot was deep black and well aerated, having been twice dug out in previous experiments. Eight rows of eight squares were arranged, each square being 3×3 ft. The depths of planting in the successive rows were 3, 6, 9, 12, 18, 24, 30 and 36 inches. Only four tubers were planted per square in order that they might make their maximum growth. Each tuber was planted in a separate hole half an inch in diameter and the proper depth. This depth was checked by lowering the tuber at the end of a string of the proper length. Even with this precaution, at the end of the experiment, tubers were nearer the surface in some cases than at the start of the experiment. This was due partly to washing of the soil and partly to the packing of the soil by the repeated trampling which it received.

The tubers were planted on July 20th, 1921. The first shoot appeared on August 15th, 1921, and the plants were dug out in April 1922. Each plant was carefully excavated, measurements and plottings being made as the work advanced, and the plants mounted as nearly as possible in their natural position and photographed afterwards. This experiment was one of the most illuminating as to the method of growth of the plant from tubers.

The following are some observations.

(a) Germination.

Table IV shows how and when the shoots appeared. From this table it is clear that the depth 9 to 18 inches was a layer favourable for vigorous growth of the parent tubers and the plants derived from them. By the end of August all tubers in the depths 3 to 12 inches had sprouted. The reduction

in the germination percentage at the lower depths in this experiment and in Experiment X is noticeable. The tubers in both experiments were brought from the same area in the Empress Gardens, Poona.

TABLE IV.

Planting in holes at different depths on the Poona Agricultural College Farm.

Depth of planting in inches	Tubers planted	No. of shoots	Tubers germinated	First appearance of shoots	Date of final observation	
3	32	38	28	Growth poor and less extensive	15th August	22- 8-21
6	32	34	29	extensive	19th "	"
9	32	29	30	Growth very vigorous and extensive	29th August	20-10-21
12	32	16	15	extensive	30th "	"
18	32	9	9	extensive	1st week of September	"
24	32	16	16	Growth poor and less extensive	Middle of September	20-10-21
30	32	4	4	extensive	1st week of October	"
36	32	2	2	extensive	"	"

Experiment X.

This was to determine the germination and also the density of production of new tubers at different levels. Twenty-four squares of one square metre were plotted in four rows of six squares each. The following were the depths at which planting was done, three squares being devoted to each depth: 3, 6, 9, 12, 18, 24, 30 and 36 inches. Murum occurred at 18 inches and, in depths below this, the pit was, on refilling, filled with black soil. 400 tubers were planted regularly in each square at the depths mentioned. This experiment was carried out in Modi Bag, the fruit area of the College Farm. The tubers were dug out of the highly infested area of the Empress Gardens, Poona, covered with moist earth. The tubers were washed, dried with cloth and weighed. On placing in the pits a little water was sprinkled on them and the earth then filled in. The earth was moderately packed but not rammed. The experiment started on 6th June, 1921, and the pits were dug out finally from 13th to 21st October, 1921, when most of the aerial shoots were withering. The rainfall before planting was 2.96 inches and during the experiment was 14.45 inches.

Shoots began to appear first in the first week of August in the squares with 12 inches deep planting. This was followed by sprouting in the 18 and 24 inches squares, the latter in the last week of September. The squares with planting at 30 inches produced no aerial shoots till November. The 36 inches deep squares showed shoots on 28th and 29th of September, 1921.

Shoots from the 3, 6 and 9 inches squares began to appear from the second week of September. The shoots were few and with a small number of leaves. The leaves were narrow and not vigorous. These squares and also the 30 inches squares (which had not then shown shoots) were left undisturbed until July 1922, when they were dug out, having received 5.26 inches more rain.

These results call for the following remarks :—

(1) Poor germination at 3, 6 and 9 inches.

This is directly contrary to the majority of our experiments with planting at these depths. The only likely explanation is to be got from a perusal of the rainfall and temperature graphs for the month of June (Graph 1). It will be observed that soil and air temperatures were high at the time of planting and again at the end of the month, and that with the exception of the half-inch rainfall on the 10th and 20th there was little precipitation. The soil, moreover, was only moderately packed and not rammed and hence probably more conductive of heat. It is, therefore, possible that the dryness and heat of the period caused the lack of germination. This, however, is only suggested as the one explanation that at present appeals to us. All these squares showed droppers which seldom penetrated below 18 inches.

The 12 inches deep squares showed the best germination but even here the percentage of germination was low.

In the 12, 18 and 24 inches squares the shoots after reaching the surface had produced tubers and chains of tubers in the 9 inches to 18 inches levels.

Table V shows that the depth 9 to 18 inches was a layer favourable for the vigorous multiplication of tubers, and for the plants derived from them. By the first week of October all the tubers in the depths 3 to 12 inches had sprouted. The very great difference in germination percentage between the tubers at these depths in this experiment and in the one immediately previous is noticeable. The tubers in both experiments were brought from the same area in the Empress Gardens, Poona. Both lots, however, were for all practical purposes alike in quality and kind. The difference in germination may be due to one or all of the following factors :—

- (1) (and probably most important) the much more favourable rainfall and temperature at the time of the inception of the other experiment ;
- (2) the much better soil in the other experiment ;
- (3) the wider planting.

In the squares devoted to tubers planted at 30 and 36 inches depths growth was on the whole poor. The shoots produced persisted forming successive leaves while the old leaves died, but there was no multiplication of shoots.

The low germination percentage at these depths again seems to indicate that some tubers are specially adapted to germinate at lower depths and that these are specially formed by the plant on deep "droppers."

TABLE V.

Planting tubers at different depths on July 6th, 1921. Germination of original tubers and density of new tubers at different levels.

Row No.	Quadrat No.	Depth of planting 400 tubers in each quadrat	No. of tubers germinated	Total No. of new tubers with average at each depth	DENSITY AT VARIOUS DEPTHS			
					Surface to 6"	6" to 9"	9" to 18"	18" to 24"
I.	1	3"	10	52	10	30	10	2
	2	"	23	46	7	16	20	3
	3	"	11	29	4	10	15	0
	4	6"	13	53	6	22	24	1
	5	"	41	78	9	29	39	1
	6	"	35	26	4	8	12	2
II.	7	9"	53	146	69	53	18	6
	8	"	2	26	10	3	13	0
	9	"	5	35	9	9	17	0
	10	12"	130	155	40	40	70	5
	11	"	25	55	16	10	25	0
	12	"	43	52	26	5	20	1
III.	13	18"	30	72	39	20	10	3
	14	"	27	48	24	16	4	4
	15	"	9	50	15	10	16	9
	16	24"	4	60	8	10	22	20
	17	"	4	63	4	8	25	26
	18	"	29	138	21	6	40	71
IV.	19	30"	12	31	15	2	10	4
	20	"	18	50	20	4	23	3
	21	"	7	16	10	0	6	0
	22	36"	3	8	4	0	4	0
	23	"	3	5	3	1	1	0
	24	"	6	2	2	0	0	0

Experiment XI.

In all the experiments about the germination of tubers buried to different depths, recorded in the previous pages, the tubers were planted in pits. To locate more certainly the planted tubers both at time of planting and at time

of digging out, two wooden boxes and one iron box were placed in a large pit dug in the Lavala Experiments Plot with wire floors at different depths.

The boxes were 3 ft. $\times$ 3 ft. $\times$ 3 ft. and wire gauze pieces 3 ft. $\times$ 3 ft. were placed at every 6 inches depth on stretched wires. The meshes of the wire gauze allowed the rhizomes to pass through but hindered the shifting of the tubers.

Each box was devoted to two depths.

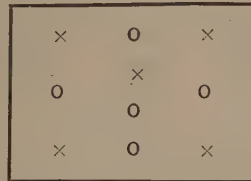
The following table gives the dates of planting and the number of tubers planted at these depths.

Date	27-7-23	I	Wooden box 3' $\times$ 3' $\times$ 3'	Five tubers planted at the depth of 6 inches
"	"	I	" do.	1 foot
"	17-7-23	II	" do.	1 $\frac{1}{2}$ feet
"	"	II	" do.	2 "
"	16-7-23	III	Iron box do.	2 $\frac{1}{2}$ "
"	"	III	" do.	3 "

The ten tubers in each box were laid down in such a way as not to interfere with the growth of each tuber.

$\times$ Tubers at the lower level.

O Tubers at the higher level.



The tubers were planted at their proper depths and the soil was put in and uniformly packed. The gauze was placed before fitting the upper layers. The boxes were watered in the beginning. The boxes were finally dug out from 20th November to 30th November. The soil was carefully removed and the original tubers with their subsequent growth were kept intact showing visibly the growth of the plants and the formation of tubers to various depths.

Box	I	Original No. of tubers	Depth of planting	Germinated	Empty	Details
		5	6"	3	2	Tuber (i) Vertical rhizome with no new growth. (ii) Empty. (iii) Vertical rhizome with a sprouting tuber in the axil of the swollen shoot. (iv) Vertical rhizome and a chain of two tubers horizontal to the depth of 6 inches. (v) Not found.

Box I	Original No. of tubers	Depth of planting	Germinated	Empty	Details
	5	1"	3	2	Tuber (i) Empty. (ii) Two vertical shoots one with a swelling at 6" depth with a horizontal rhizome with a tuber and one ascending rhizome with a tuber. (iii) One vertical shoot with a dropper of one tuber to the depth of 1½ ft. (iv) Vertical rhizome with a new shoot at the surface. (v) Empty.

Box II	Tubers planted	Germinated	Details
18"	5	5	Tuber (i) One vertical rhizome swelling at 9 inches producing one more shoot. Horizontal chain at 18 inches with 2 tubers, the middle one producing a vertical rhizome with a tuber at 16 inches. (ii) One vertical rhizome with a swelling at 12 inches. One horizontal chain at 18 inches with one tuber which produced four tubers in the layer 18"-24", one of which again sent a rhizome reaching the surface. (iii) A vertical rhizome and a dropper with a tuber at 24 inches. (iv) A vertical rhizome. (v) A vertical rhizome with a swelling at 12 inches producing a horizontal chain of 12 inches.
24"	5	4	(i) One vertical rhizome. Another vertical rhizome with two tubers at 20-18 inches. (ii) A horizontal chain of two tubers, the middle one producing a vertical shoot. (iii) Empty. (iv) One vertical shoot with two tubers near the surface, the middle one sprouting. (v) Remarkable growth—straight vertical rhizome with a swelling at 9 inches. A dropper of 3 tubers from the original, the middle of the three producing two tubers on a horizontal chain at 30". The first of this growth sending a vertical rhizome, straight to the surface forming a shoot.

Box III	Total planted	Germinated	Empty	Details
30"	5	2	3	Tuber (i) Empty. (ii) Vertical rhizome. New shoot at the surface. (iii) Empty. (iv) Empty. (v) Vertical rhizome with a swelling near surface.
36"	5	1	2 empty 2 in shrivelled bits.	(i) Vertical rhizome with a tuberous swelling at 6 inches with roots and one shoot.

The following table gives the number of shoots and tubers formed from each box :—

DEPTH	TUBERS		SHOOTS
	Original	New	
6"	5	3	3
1'	5	3	4
1½'	5	8	8
2'	5	11	7
2½'	5	1	2
3'	5	1	1
	30	27	25

It was not easy to take photographs of the growth in the three dimensions and the boxes were placed in the museum.

This experiment gave visible evidence and corroborated the results of the first experiments about the germination of the tubers and their subsequent growth and the optimum depth of tuber formation.

2. *Experiments in damaging the tubers.*

The next series of experiments deal with the effect of various operations on the tuber. These were cutting, scraping and exposure to sun heat and oven heat. The ulterior aim of these experiments was to get information as to the

probable behaviour of tubers injured or exposed by implements in the course of field cultivation.

Experiment XII. By Wounding.

Two white tubers were cut into four pieces and planted one inch deep in pots on February 7, 1921. All pieces germinated on February 21.

Two white tubers were scraped so that all tissue outside the cortex was removed. These were planted on February 7 and germinated on March 8.

Two black tubers were scraped and quartered, and planted on February 7. These germinated on March 2.

Two black tubers were scraped and planted on February 7. These germinated on February 16.

All the above were watered twice a week. These results were confirmed by a similar experiment in August 1922.

Experiment XIII.

Tubers were also damaged artificially by pricking and cutting (without actually severing the parts) and then planted. Such wounds are often blocked by gum produced by the tuber. Wounded tubers kept in the sun or in an oven at 98°F. (37°C) for seven days did not germinate. This was probably the effect of the temperature, as we shall show later. Of tubers merely wounded and not exposed to high temperatures the majority germinated.

In tissue near a wound the cells are full of a yellowish fluid and the cells next to these have starch grains degenerating in size and number. The fluid in these cells gives no reaction with hæmatoxylin, eosin, acid fuchsin, or safranin. Methyl green stains it slightly. The fluid may possibly be degenerated starch.

We may conclude therefore that damage by implements even if considerable (to the extent of peeling the tubers and of quartering them) is not likely to interfere with their germination. It may also be pointed out that such damage is likely to be on the whole rare, because of the small size of the tuber as compared with the blade or share of any implement, and because of the protection afforded by the earth.

Experiment XIV. By Exposure.

Tubers collected in the first week of December 1920, were put out in the sun daily from 10 A.M. to 6 P.M. until February 1, 1921, when ten of them were put to germinate in black soil in pots. Another ten were kept in the sun till March 2 and similarly planted. Both pots were watered daily.

None of the tubers germinated.

Experiment XV.

On May 6, 1921, four lots of 20 tubers were used. Each lot was buried three inches deep in dry soil in pots and the pots exposed to the sun on the College veranda.

The result is shown in Table VI. Again none of the tubers germinated. Table VII gives the details of another series.

TABLE VI.

Effect of exposing lavalva tubers to sunlight.

Lot No.	EXPOSED		Exposed for days	REMARKS
	From	To		
I ..	6th May	14th May, 1921	8	All of these failed to germinate though watered every day after planting in good black soil.
II ..	"	20th "	14	
III ..	"	27th "	21	
IV ..	"	16th June, 1921	40	

TABLE VII.

Effects of exposing lavalva tubers to sunlight.

	Lot No. I	Lot No. II	Lot No. III	Lot No. IV
Exposure started ..	30-5-21	30-5-21	30-5-21	30-5-21
Weight of 20 tubers in gram.) Before exposure ..	17	15	20	17
..) After exposure ..	5.5	7	7	6
Loss of weight ..	11.5	8	13	11
Percentage of loss ..	67.6	53.3	65	64.7
Exposed for days ..	11	15	24	30
Rains in inches during exposure ..	0.725	0.915	1.295	1.295
Planted (to test effects of exposure) on ..	11-6-21	16-6-21	24-6-21	30-6-21
Germination ..	0	0	0	0

Experiment XVI.

A field experiment was now arranged. A piece of ground was laid out in twelve plots of a square metre each (four rows of three plots each). In each square plot 400 tubers were planted. In the first row these tubers were laid on the surface of the soil. In the second row they were buried three inches deep in the dry soil. In the third row the tubers were placed on the surface, but 20 litres of water was sprinkled on them and on the soil at the time of planting. In the fourth the tubers were planted three inches deep and 20 litres of water sprinkled over them at the time of planting and before the addition of the top three inches of dry earth.

The total water contents of the soil layers on which the tubers rested was determined before the sprinkling of the water. The water content in each case was—

Row	I	..	..	..	..	..	2.38 per cent.
"	II	..	..	..	..	..	7.38 "
"	III	..	..	..	..	..	3.62 "
"	IV	..	..	..	..	..	6.30 "

It will be seen that the soil was very dry, as one would expect at the end of the hot weather. Such soil should theoretically be a good absorber of moisture and a good conductor of heat. The first rains came on June 3, 1921. By June 15 (20 days after planting) the rain-fall amounted to 0.915 inches. The tubers, therefore, had been exposed before the first rains to eight days continuous sunshine. Shoots appeared in the fourth row but not in the others by June 15 and this condition of things continued throughout the months of June and July in which there were 25 rainy and 36 sunny days. The term rainy day means a day in which there was any rain whatever. Of continuous rain there were only 17 days in the two months. The plots were allowed to remain undisturbed till September 20, 1921, up to which date they had received a rainfall of 13.21 inches. There was still no germination in rows I, II and III. The ground sloped slightly towards plot 12, the last plot of row IV, while plot 11 was well drained. Row IV was dug out on September 20 and the tubers from the other plots collected and weighed. Table VIII shows the results.

TABLE VIII.

Experiment XVI in exposing tubers to sunlight.

Results of Row No. IV.

				Quadrat No.			TOTAL
				10	11	12	
Number of tubers:	..	..	..	400	400	400	1,200
Planted on	..	..	..	26-5-21	26-5-21	26-5-21	
Dug out on	..	..	..	21-9-21	22-9-21	22-9-21	
Number of tubers:—							
Dormant — Empty	..	..	..	148	194	116	458
" Normal	..	..	..	0	9	58	67
Germinated	..	..	..	45	16	155	216
New tubers	..	..	..	249	41	251	541
No. of shoots on the surface	..	..	..	126	45	261	432

Note. Of the original 1,200 tubers in this row only 18 per cent. germinated, 5.5 per cent. failed to germinate, 38.16 per cent. were empty of contents and of the remaining 38.34 per cent. no trace was found. Nevertheless 18 per cent. (216 tubers) which germinated during three months of the favourable season produced additional (541) new tubers. Thus in place of the original 1,200 tubers, 824 tubers (68.6 per cent.) were found at the end of the experiment.

This experiment indicates—

- (1) the amazing efficiency of an eight-day exposure to the May sun even at a depth of three inches in dry soil ;
- (2) the way in which a moist soil layer at three inches deep keeps the tubers alive ;
- (3) the speed with which tubers multiply again.

Experiment XVII.

This experiment was laid out in the same way as the last with the following modifications.

(1) Soil moisture determination was done both before and after the experiment.

(2) In Rows III and IV soil moisture determination was in addition done both before and after the sprinkling of water at the beginning and after the draining off of surplus water at the end of the experiment.

(3) Ten litres of water was used for sprinkling each square instead of 20.

(4) 200 tubers per plot were used instead of 400. Only new tubers at the ends of rhizomes were used. The experiment was started on November 9, 1921.

Soil moisture percentages (total water) were—

Row	I	..	..	..	..	19.9
„	II	..	..	..	..	22.5
„	III	before watering	..	..	..	20.2
		after	..	..	..	37.5
„	IV	before	..	..	..	26.5
		after	..	..	..	44.3

Soil moisture percentages at the end of the experiment on December 28, 1921, were—

Row	I	..	..	..	..	17.6
„	II	..	..	..	..	18.9
„	III	..	..	..	..	28.7
„	IV	..	..	..	..	35.2

These plots received neither rain nor irrigation water during the experiment. Again there was no germination in the first three rows and this is all the more striking when one considers the marked increase in the soil water. Row IV did not show germination till November 21. Germination in Row IV was as follows :—

Square	10	..	..	..	20 tubers out of 200
„	11	..	..	..	25 „ „ „ „
„	12	..	..	..	3 „ „ „ „
TOTAL					48 „ „ „ 600
or 8 per cent.					

Rows I to III were left untouched till January 6, 1922, but there was no germination in them.

This experiment confirmed the effectiveness of exposure.

Experiment XVIII.

In the May experiment the maximum temperatures of the atmosphere, surface of the soil and soil layer three inches deep were 108°, 111° and 117°F. (i.e., 42°, 44° and 47°C. respectively). In the November experiment the same sites had the maxima of 101°, 105° and 99°F. (i.e., 38°, 41° and 37°C. respectively). In order to determine in controlled conditions the degree and duration of temperature necessary to destroy the life of the tubers a preliminary experiment was arranged. The range of temperature was 34° to 49°C., i.e., 91° to 120°F. and the duration ten minutes to seven hours. Heating was done in a steam oven. The tubers thus heated were planted in soil at three inches deep and watered. Most of these germinated. The loss of weight due to this artificial heating was 16·8 per cent. In the field experiments the heating was for several days and the loss in weight up to 50 per cent.

Details of the method are these. Lots of ten tubers were placed in paper bags and kept at a constant temperature in the oven for the time required. After heating they were weighed and after one day in wet soil they were again weighed to find out how much water they had reabsorbed. It was found out that they made up their original weight and in many cases exceeded it. Details are given in the Appendix.

If we consider the first case in which the tuber has not absorbed up to its original weight (ten minutes exposure 98°F. (37°C.)) we find that there was no germination. In the next case of the kind, however (one hour exposure at 109°F., i.e., 43°C.), seven out of the ten tubers germinated. The same is the case for 30 minutes at 115°F. (46°C.). In the case of one hour exposure at 119°F. (48°C.), where the tubers had not absorbed up to their original weight the germination was eight out of ten. In the case of 115°F. (46°C.) there is a loss at all durations except the four hour one where the gain is very small, and a much reduced germination. At 121°F. (49°C.) there is a loss on the original weight in three out of five cases, but the germination is much better. From these figures it is plain that one cannot yet come to definite conclusions as to the relation of desiccation to germination. There is, nevertheless, noticeable a tendency, as the temperatures and durations increase, for the desiccation to advance to such an extent that tubers do not make up their original weight after one day in moist soil.

Experiment XIX.

Armed with the above experience we now planned another experiment in artificial heating. Healthy plump tubers from the Empress Garden were used. These were divided into four lots of ten each, and each lot duplicated. One lot of ten of each pair was exposed in a shallow paper dish and the duplicate lot in a similar dish but just covered with dry earth. The temperature of the oven was 104°F. (40°C.) all the time and the four lots were heated for three, seven, eight and fourteen days respectively. The tubers were weighed before and after the heating, then placed in wet blotting paper for a day to measure the amount of water reabsorbed, planted two inches deep in soil and watered to test germination. Heating began on March 20, 1923, and continued till April 4, 1923. Germination was watched till July 2, 1923. For actual weight, etc., see the Appendix.

The main results were :—The percentage of loss of weight increased with the period of exposure and the losses are greater in the series simply exposed in paper dishes than in those exposed in an earth layer.

The reabsorption of water from blotting paper was inversely proportional to the time of heating. Taking both series (open dishes and earth layer) the average of the amount by which the tubers failed to make up their original weights was 20 per cent.

The germination results show clearly that in spite of these losses, heating up to eight days by no means destroyed the vitality of the tubers, while heating up to fourteen days was completely destructive.

Experiment XX.

Still another experiment of the same type was designed to confirm the effects of long exposure to artificial heat. Four lots of ten tubers, again duplicated and again similarly exposed, were put in the oven at the same temperature, this time for fifteen days. Heating began on April 5 and ended on April 20, germination being studied up till July 2. The average deficit of reabsorption for both series was 35.1 per cent. and only one out of eighty tubers germinated, this being one from a paper dish without earth. For details, see the Appendix.

Experiment XXI.

We now returned to the open field for a last confirmatory experiment. The maximum temperature of the earth in March 1923 being 104°F. (40°C.) the same as the oven, we exposed four lots of 25 tubers in pots, one lot on the surface of dry earth, one lot on the surface of wet earth, one lot two inches deep

in dry earth and one lot two inches deep in wet earth. Weights of tubers were again determined before and after exposure. Exposure without moisture lasted only for five days, for there was rain on March 24 and 26 and the pots got a total of 0.16 rain on these two days. Conditions, therefore, rather favoured the germination of the tubers. Nevertheless the tubers fully exposed on the surface of dry soil had all been killed, and the germination of all except the last pot was unsatisfactory. In the last pot the germination was 92 per cent. indicating the considerable advantage derived from the originally wet seedbed.

SUMMARY.

Summing up all these exposure experiments we see that a temperature of 104°F. (40°C.) in an incubator has to be applied for fourteen days to be effective. The same temperature in the field, where tubers are either exposed to the sun or are not deeper than three inches in dry earth, is effective within eight days. This is another important indication for our guidance in dealing with the plant and suggests the need for some agricultural operation which will bring the maximum amount of tubers to the surface in the hottest part of the year.

3. *Experiments on the effect of spraying with various chemicals.*

Experiment XXII.

Since spraying with copper sulphate and other chemicals has been found effective in killing certain other weeds, experiments were designed to test the effect of such spraying on the lavalva weed.

These were first done in two ways, (1) by watering plants grown in pots, (2) by mixing the chemical with the soil and then planting tubers in the soil.

(1) *Watering plants in pots.*

The chemicals used were common salt, quicklime, magnesium sulphate, ferrous sulphate, copper sulphate. These chemicals were administered in 2, 4, 6, 8 and 10 per cent. solution strengths. There were for each treatment two series of pots, one with single tubers and one with chains of tubers. Two pots with single tubers and two with chains, a total of 20 pots for each chemical.

The pots were filled with good river soil on June 21, 1921, and the tubers and chains of tubers (whole systems with the aerial shoots) were planted on June 22 and 23. The plants were watered with ordinary water till June 27.

On that date two and a half litres of the solutions were poured on to the soil in each pot after stirring the soil. The pots were kept under observation till July 27. During this period they received 7.27 inches rain.

The results were as follows :—

Common salt :—All pots showed caked and cracked surface soil. All shoots withered, but those from plants in the pots treated with 2, 4 and 6 per cent. solutions revived, producing new leaves. Unsprouted tubers (whether solitary or in chains) remained dormant till the third week. Then all the tubers in the 2 and 4 per cent. pots sprouted, but in the 6 to 10 per cent. pots only two or three tubers sprouted. In the 10 per cent. pot the few tubers that sprouted did not survive.

Quicklime (slaked) :—This liquid was added to the soil when cool. There was no evil effect on either shoots or tubers. All the solitary tubers sprouted.

Magnesium sulphate :—The effect was stimulation of growth. The solitary and chain tubers sprouted. The shoots were deep green and flowered early and profusely.

Ferrous sulphate :—The shoots turned yellowish and sickly in the first week and later revived.

Copper sulphate :—The shoots turned yellowish and sickly during the first week. The plants treated with 2 and 4 per cent. solutions revived in the second week. The plants with the 6 to 8 per cent. treatment survived till nearly the end of the experiment and then died. The plants under the 10 per cent. treatment died at the beginning of the experiment. Tuber germination was delayed till the third week, but few of the shoots survived in any strength of treatment.

(2) Pots with chemicals added previously to the soil.

The soil in the pots was wet with rain. The moisture was determined and the amount of chemical added so as to be a percentage of the dry weight of the soil. The actual percentages were close to 2, 4, 6, 8 and 10 of the dry weight of the soil in each pot. The same series were employed (solitary tubers and tubers in chains with the aerial parts intact). Planting was done on July 27. The plants were observed for a month during which 3.71 inches of rain fell. The effects were similar to those in the first experiment but were more severe in the case of common salt and copper sulphate. The lime and the magnesium sulphate had no evil effects. In the ferrous sulphate pot the tubers germinated but withered in the second week. In the copper sulphate pots all the tubers sprouted in the third week but withered in spite of the rain.

(3) On the basis of these indications 3×3 ft. quadrats of lavalva infested soil were sprayed as follows :—

One with 2 per cent. common salt, one with 2 per cent. copper sulphate, one with hot water and one kept as a control. The hot water treatment was

supposed to be with boiling water. By the time the water reached the plants however, the temperature had fallen to about 62°C. Hence so far as temperature went the treatment was useless. The treatment, however, was continued to the beginning of May 1922. The other treatments started on November 1921 and continued till October 1922 twice a week, being 100 applications in all.

The area between the quadrats was numbered and dug up and the number of tubers in each section counted. This indicated the tuber population per 27 cubic ft. to be 875, a high figure.

The soil was put back into the trenches, but the tubers were not put back. The idea was to keep the quadrats free from encroachment from outside tubers.

The countings showed the decrease of tubers as one goes deeper into the soil and also that there are many more tubers than shoots.

Method :—Each quadrat was sprayed twice a week with a 2 per cent. solution of the chemical.

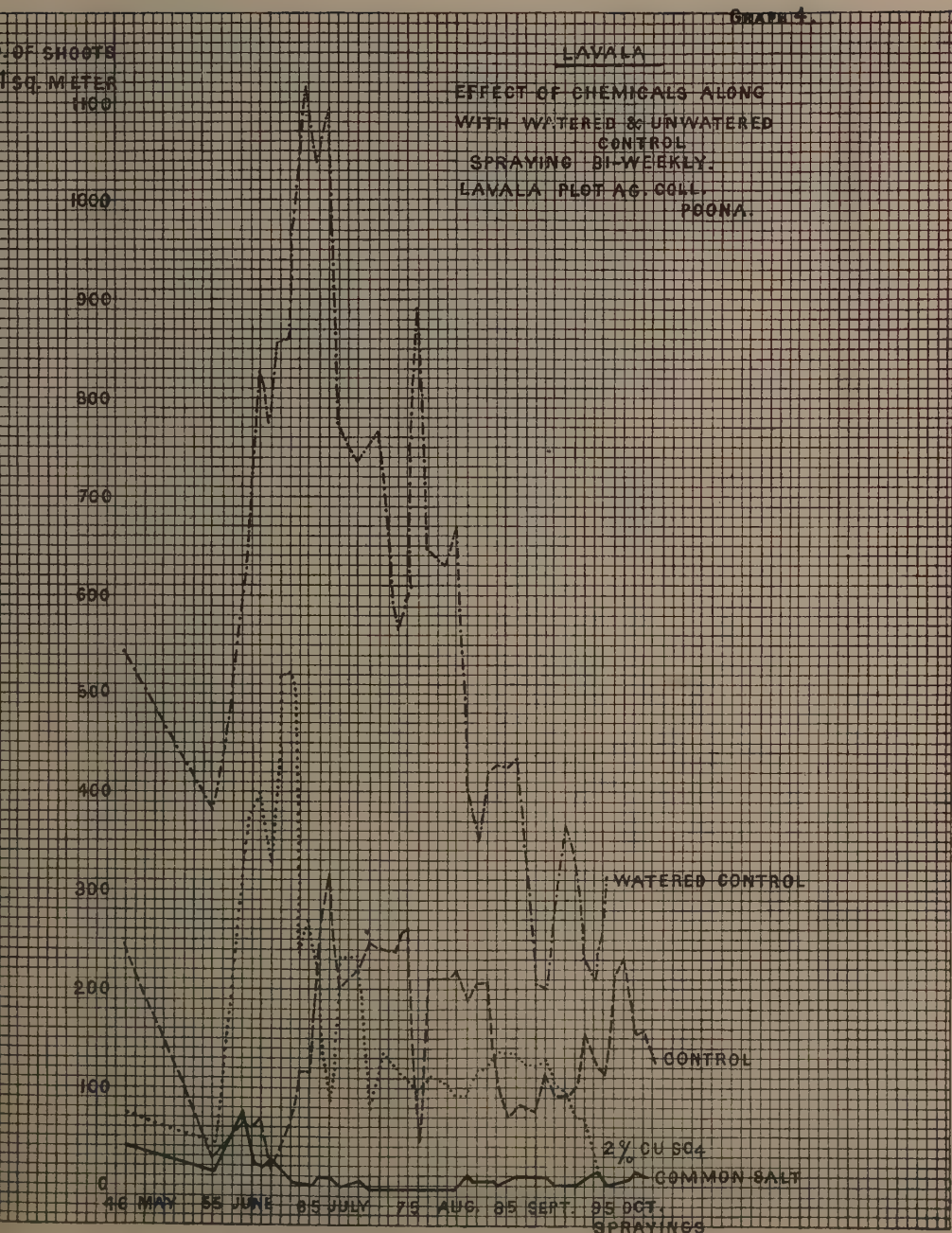
Spraying was done from 25th November, 1921. After the 46th spraying the shoots in all the quadrats were counted at the time of each spraying and the result is shown in Graph 4. The greater efficiency of the common salt is clearly shown. It is also observable that the number of shoots in all plots markedly decreases after the rains.

After the 67th spraying the soil at various depths in the salt sprayed quadrat was analysed with the following result.

TABLE IX.
Soil samples.

	I	II	III	IV
Depth	6"	6" - 12"	12" - 18"	18" - 24"
Chemical common salt	1.77	0.53	0.046	0.046
		per cent.		

From these same four depths and from this quadrat four pots were filled with soil and in each pot 50 seeds of jowar (*Andropogon Sorghum*) and five lavalas tubers were planted to test the growth of these plants in the soil which had been subjected to the spraying. The jowar in all the pots germinated. In pots 1, 3 and 4 the seedlings were sickly, but in pot 3 they improved afterwards and produced plants three feet high which headed out. Pots 1 and 4



GRAPH 4.

did not produce earheads. Pot 2 produced healthy plants which headed. These pots were watered daily. There was therefore probably washing out of the salt. Even with this, however, the surface layer seems to have had too much salt for the health of the jowar. The poor growth from pot 4 may possibly be explained by the fact that this was subsoil. In addition, 100 jowar seeds were planted on the remaining undisturbed part of the salt-sprayed quadrat and allowed to get the rain (from 20th July, 1922). The seeds germinated but withered, and only three seedlings on the border where presumably there was less salt grew three feet tall and headed out. The indications are that the surface soil was too salt for the growth of jowar.

The lavalas tubers in the pots first mentioned all germinated.

One-fourth of the quadrat was then dug out and the total number of tubers found was 121. The distribution was as follows :—

TABLE X.

Quadrat II (Salt). Area (2.25 sq. ft.)

Depth	0" - 6"	6" - 12"	12" - 18"	18" - 24"	TOTAL
Tubers	12	38	61	10	121

Five healthy-looking tubers from each depth were selected and planted in good soil in pots on 20th July, 1922. All failed to germinate except three from the lowest layer. The others on 20th August, 1922 were found to be shrivelled. Treating with 2 per cent. salt, therefore, seems to be effective in killing the shoots and the tubers in the upper layers, but it does not kill the tubers which are deeper and it renders the upper layer of soil unfit for jowar.

The application of chemicals was stopped after the 100th spraying (20th October, 1922). During the period from that date to 14th November, 1922, there was an increase in the number of shoots in the salt plot. This was found to be due to invasion from the control plot, the rhizomes having crossed the previously dug out and refilled trench. The remaining three-fourths of the salt plot were dug out on 14th November, 1922, and in the first foot were found 40 shrivelled and 30 plump tubers, in the second 20 shrivelled and ten plump tubers. The plump tubers were all transplanted into good soil the same day in Modi Bag. Only two tubers from the first foot and three from the second foot germinated within a week. The others failed to germinate.

In the copper sulphate plot the chemical seemed to kill the foliage (which was to be expected) as the leaves were made to turn yellow, but these were constantly replaced by new leaves and new shoots. The whole quadrat was dug out on 17th October, 1922 with the following result :—

TABLE XI.

Chemical CuSO₄.

Depth	6" - 6"	6" - 12"	12" - 24"
Tubers	248	392	45

4. *Experiments in repeated removal of the shoots.*

The next series of experiments deals with the effect on the tuber of repeated removal of the aerial parts. Such removal of aerial parts is all that occurs in ordinary hand-weeding and in a good deal of weeding by implements, hence it was necessary to determine the effect of such removal. Theoretically, if one could continuously remove all leaves as they appeared one ought to be able to exhaust the reserves of food in the tubers.

Experiment XXIII.

A single tuber freshly dug out was soaked in water for 24 hours and planted two inches deep in black soil in a pot on June 1, 1920. This tuber when dug out weighed 0.87 gm. and after soaking 0.92 gm. The shoot was cut off at intervals by a pair of scissors as close to the soil as possible. The dates of cutting and number of intervening days were as follows :—

Date of cutting	Interval in days
11-6-20	10
3-7-20	23
2-8-20	20
11-10-20 (last shoot)	105
20-12-20 (no shoots)	tuber dug out.

The plant throughout the experiment was watered twice a week.

The tuber when dug out weighed only 0.32 gm. It was shrivelled, only the outer skin and the wood fibres being left. It is remarkable that although the plant was not allowed to develop its shoot the tuber took five and a half months to die. The tuber lay dormant for a long time before making its final attempt to produce a shoot.

Experiment XXIV.

On June 11, 1921, 24 freshly dug tubers were weighed and planted two inches deep in good black soil, each tuber in a separate pot. Shoots were cut off as in the last experiment. Table XII gives the data. No tuber made

more than six successive attempts at shoot production. After three months no shoots appeared. The pots were kept under observation till June 11, 1922, when all the tubers were dug out. Eleven tubers were in shreds and the other thirteen hollow and without starch. There had been no production of new tubers.

TABLE XII.

Effect of frequently cutting off the aerial shoot produced from the Lavalu tuber.

Experiment started on 11th June, 1921

ended on 11th June, 1922.

Tuber No.	Label No.	No. of shoots cut at a time	Date of cutting	Interval between two cuttings (Days)	Original weight of tuber	Final weight of tuber
1	37	2	20-6-21	9	Grm. 1.070	Grm. 0.120
		1	29-6-21	9		
		1	15-7-21	16		
2	38	1	18-6-21	7	1.050	0.257
		1	27-6-21	16		
		1	6-7-21	9		
			22-8-21	47		
3	39	1	27-6-21	16	0.837	0.113
		1	6-7-21	9		
		1	23-7-21	17		
4	40	2	20-6-21	9	1.055	0.807
		1	27-6-21	7		
		1	6-7-21	9		
5	41	1	18-6-21	7	1.104	Shreds.
		1	27-6-21	9		
		2	4-7-21	7		
3	42	1	18-6-21	7	1.052	"
		1	27-6-21	9		
		2	4-7-21	7		
7	43	2	18-6-21	7	0.905	"
		1	23-7-21	35		
8	44	2	23-6-21	12	1.050	"
		1	4-7-21	11		
		1	23-7-21	19		
9	45	1	18-6-21	7	0.950	"
		2	27-6-21	9		
		1	4-7-21	7		
10	46	1	18-6-21	7	0.870	0.529
		1	23-6-21	5		
		1	29-6-21	6		

TABLE XII—*contd.*

Tuber No.			Label No.	No. of shoots cut at a time	Date of cutting	Interval between two cuttings (Days)	Original weight of tuber	Final weight of tuber
11	..	..	47	2 1 1	20-6-21 27-6-21 19-8-21	9 7 53	Grm. 0.840	Grm. Shreds.
12	..	..	48	1 2 2 1	18-6-21 27-6-21 4-7-21 18-7-21	7 9 7 14	1.520	„
13	..	..	49	1 1	18-6-21 26-6-21	7 9	1.200	„
14	..	..	50	2 1 1	23-6-21 4-7-21 18-7-21	12 11 14	1.180 1.500	„
15	..	..	51	No shoot was found. Tubers all in small bits.				
16	..	..	52	2	18-6-21	7	1.350	1.020
17	..	..	53	2 1 1 1	18-6-21 29-6-21 13-8-21 2-9-21	7 11 45 20	1.285	Shreds.
18	..	..	54	2	18-6-21	7	1.287	0.169
19	..	..	55	1	16-6-21	5	1.902	0.731
20	..	..	56	2 1 1	18-6-21 27-6-21 6-7-21	7 9 9	1.609	0.329
21	..	..	57	1 1 1 1	18-6-21 27-6-21 15-7-21 28-7-21	7 9 18 13	1.409	0.625
22	..	..	58	1 1 1 1	27-6-21 12-7-21 10-8-21 29-8-21	16 15 29 19	1.452	0.914
23	..	..	59	1 1	16-6-21 23-6-21	5 7	1.435	Shreds.
24	..	..	60	1 1	18-6-21 27-6-21	7 9	1.695	0.642

These two experiments confirm the theory that repeated removal of the aerial parts will kill a tuber. This seems simple. The following experiments will show how the treatment works in actual practice in weeding in the field.

Experiment XXV.

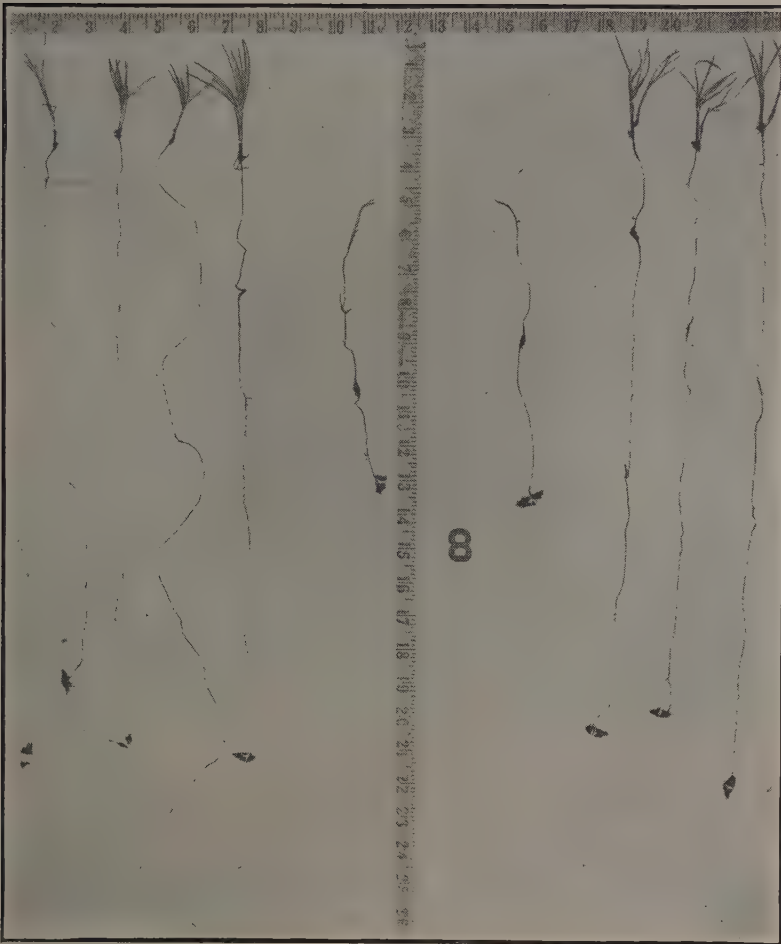
This experiment had a double purpose (1) to test the effect of weeding on laval colonies in a small plot, (2) to compare the effectiveness of two methods of weeding.

As regards point (2) :—We have shown that each aerial shoot has at its base a bulb (Plate VI, 2) not a tuber, from which arise horizontal rhizomes and droppers. Ordinary weeding by the weeding hook (*Khurpi*) does not remove this bulb. If weeding were done to tear up this bulb then such weeding ought to be much more effective. Accordingly a coarse fork was made which was thrust under the bulb, thus levering it up. One plot was weeded with this instrument and one by the *Khurpi*. (Plate VII, 1.)

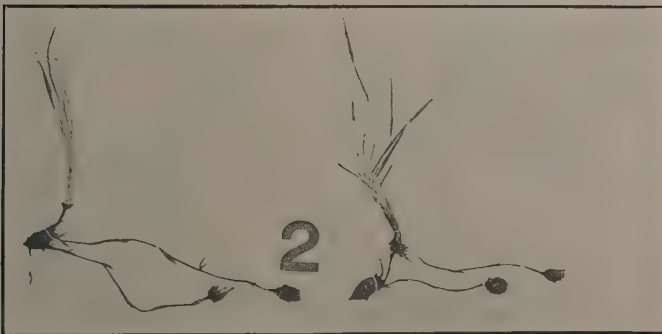
The plots were in an unirrigated part of the college farm. One plot measured 2 × 2 metres and the other 2 × 3. They should have been of the same size, but the results are made comparable by reducing them to terms of one square metre. Weeding began on September 7, 1920, and went on till May 16, 1921, when the tubers in each plot were dug out, counted and replaced. No further weeding was done till September 1, 1921; so the transplanted tubers had the full benefit of the 1921 rains. On September 13, 1921, the tubers were finally dug out and counted. The number of shoots visible was counted at each weeding. Table XIII gives the details of the experiment :—

TABLE XIII.
Weeding Experiment.

Date of weeding	Days between weeding	No. of shoots removed per weeding by		No. of shoots removed per weeding calculated per sq. metre		
		Area		Khurpi	Fork	
		Khurpi 2×2 metre	Fork 2×3 metre			
7-9-20	..	21	120	205	30	34.1
29-9-20	..	71	310	355	77.5	59.1
9-12-20	..	71	190	155	47.5	25.8
8-1-21	..	30	120	69	30	11.5
7-2-21	..	30	90	40	22.5	6.6
8-3-21	..	29	86	26	21.5	4.5
8-4-21	..	31	56	6	14	1.0
8-5-21	..	23	73	20	15.7	3.3
16-5-21	..	Tubers dug out, counted and			replaced.	
1-9-21	..	116	440	270	110	45
13-9-21	..	12	180	161	45	26.8
13-9-21	..	Tubers finally dug out.				



1. Plants from deep tubers.



2. The right-hand plant shows the "basal bulb" clearly. One rhizome emanates from it and another rhizome from the tuber below.



1. The man on the right is using the fork.



2. Weeding with Planet Junior Hoe.

Tubers at test diggings.

Date	KHURPI-WEEDED PLOT (2 × 2 metres)		FORK-WEEDED PLOT (2 × 3 metres)	
	Empty tubers	Normal tubers	Empty tubers	Normal tubers
16-5-21	86	405	172	480
13-9-21	33	113	141	126
Above figures reduced to one sq. metre as unit.				
16-5-21	21·5	101·25	28·66	80
13-9-21	8·25	28·25	23·5	21

The following points emerge :—

(1) Reduction of shoots. From September 7, 1920, till May 8, 1921, the percentage reduction in shoots by the *Khurpi* method of weeding was only 39·16; while by the fork method it was 90·28. This demonstrates the greater efficiency of the uprooting of the basal bulb.

(2) Reduction of tubers. The original number of tubers is not known. The total number of empty and normal tubers found at the end of the experiment cannot be considered as a measure of the number at the beginning of the experiment, since in the *Khurpi*-weeded plot the tubers probably multiplied considerably and in the fork-weeded plot their multiplication was probably much impeded. The figures, however, show some surprises. The first of these is the comparatively small difference in number of normal tubers between the two plots, when compared with the large difference in above-ground shoots. The still more astonishing result is the very small number of sound tubers remaining at the end of the experiment in the *Khurpi*-weeded plot.

One fact stands out prominently. Neither form of weeding had entirely cleared the ground of tubers. There were left enough to repopulate the area in a very short time.

Experiment XXVI.

This was a field experiment to repeat on a larger scale the earlier experiment on the weeding of tubers deliberately planted for the removal of their aerial parts. Pits 3 × 3 × 3 ft. were excavated in Empress Gardens and the number of tubers in each layer was counted and set aside. These tubers were

replanted in similar sized pits on the College Farm. In pits I and II, the tubers were replaced at the depths in which they were found. In pit III the tubers were mixed with the soil throughout the whole 3 ft. depth. The surface of pit II was weeded and pits I and III were kept as controls. The experiment started on November 17, 1922, and ended on October 31, 1923, when the tubers were dug out. Weeding was done once a week by the fork. No watering was given. Shoots appeared from January 13, 1923. Table XIV shows the results.

TABLE XIV.

Number of shoots from the tubers transplanted.

Weekly weeding No.	Quadrat weeded weekly II	Control quadrat (tubers in layers) I	Control quadrat (tubers mixed in soil) III
1	67	21	1
2	25	54	4
3	15	4	2
4	10	18	1
5	17	12	2
6	5	19	2
7	6	27	2
8	38	25	2
9	37	24	6
10	80	13	7
11	8	15	6
12	6	9	1
13	3	1	1
14	4	15	3
15	..	..	..
16	2	0	1
17	2	4	5
18	2	0	3
19	0	0	0
20	0	9	2
22	1	2	1
23	0	2	0
24	0	0	1
25	..	..	..
26	11	19	28
27	28	..	..
28	..	..	..
29	118	115	47
30	101	130	50
31	54	121	78
32	8	118	82
33	5	120	86
37	4	124	134
38	1	107	113
39	0	109	121

Judged by the results on the tubers the weeding in pit I has been effective. It must be remembered that these were tubers planted *ad hoc* with aerial

parts removed as soon as shown and were much in the position of the isolated tubers in pots in experiment.

In the two control plots there was a considerable total decrease in tubers and there was a decrease also in the number of viable tubers. This shows that the conditions were much less favourable in their new home than in the Empress Gardens from which they were transplanted.

Experiment XXVII.

Two adjacent plots each measuring 100×20 ft. were selected in a weed-infested area of the College Farm. One of these was used as an untreated control and the other weeded once a week by the Planet Junior Hoe with the ordinary weeding blades on it. (Plate VII, 2.) Before weeding two quadrats each 3 by 3 ft. were selected and the shoots on these counted. These were regarded as fixed quadrats and all countings done on them. Tables XV and XVI give the counts of the shoots in both quadrats and the number of tubers in the soil at the close of the experiment.

TABLE XV.

Number of shoots on the quadrats (3×3 ft.) in the experiment of weeding with a Planet Junior Hoe once a week.

No. of weeding	Date	Shoots in quadrat in plot 9 Hoe	Shoots in quadrat in plot 10 Control
1	18-8-22	494	556
2	29-9-22	110	379
3	6-10-22	229	314
4	21-10-22	122	235
5	27-10-22	185	204
6	3-11-22	158	205
7		...	..
8	17-11-22	205	138
9	24-11-22	323	254
10	1-12-22	164	253
11	8-12-22	184	396
12	15-12-22	128	105
13	22-12-22	167	393
14	29-12-22	126	243
15	5-1-23	26	341
16	12-1-23	102	105
17	19-1-23	94	327
18	26-1-23	126	364
19	2-2-23	105	297
20	9-2-23	212	245
21	16-2-23	106	107
22	23-2-23	78	312
23	2-3-23	..	102
24	9-3-23	50	310
25	16-3-23	28	217

It will be seen that this weeding was absolutely ineffective. In fact the control plot was less weedy than the weeded plot. This was partly due to the growth of grass on the control plot competing with the lavalas. We shall have more to say later on regarding the competition of grass and lavalas.

The ground was unirrigated and hard. Hoeing in this superficial manner was doubly unsatisfactory on account of the hardness of the soil and because the shallow-going implement did not uproot the basal bulb. Not only so, but the clearing away of the loose soil after a weeding revealed shoots on their way up which had escaped the hoe blades. An actual count made on January 25, 1923 gave the following figures in a 3×3 ft. square surface.

Number of shoots before weeding	28
" " " after " " " " " "	7

Two inches of loose soil were then removed and there appeared shoots wholly or partially protected from the hoes	53
--	----

(These included 21 of which the leaves had been severed but the basal bulb untouched.)

In another case the number of shoots before weeding was	35
---	----

After removal of two inches of soil there appeared (including the above 35)	129
---	-----

As it is manifestly not economic to scrape the loose soil off and then hoe, this method of weeding in hard soils does not commend itself.

Experiment XXVIII.

In this experiment four plots each 8×2 metres were treated thus.

- I. Hand-weeded twice a week by the fork uprooting the basal bulb.
- II. Untreated control.
- III. Hoeing with Planet Junior Hoe twice a week.
- IV. Hoeing with the Planet Junior Hoe once a week.

The plots were in the Empress Gardens. The adjacent ground was irrigated three times a month. The plots were not irrigated, but on February 15, water was accidentally allowed to flow over the plots.

A test digging on December 6 at the edge of all plots except the control plot gave the following results (Table XVII). Counts were made of the shoots before each weeding. Test diggings and their results are shown in Table XVIII. The first test digging was taken at the edge of the plots and the number of tubers in these diggings was probably due to invasion from neighbouring soil. The second test digging was taken

in the middle of the plots and the effect of the weeding and hoeing is apparent.)

TABLE XVII.

Depth of digging	Opposite Plot I weeded. No. of tubers	Opposite Plot III No. of tubers	Opposite Plot IV No. of tubers
Surface to 6"	437	517	491
6" to 12"	275	231	418
12" to 18"	312		
18" to 24"	75		
24" to 36"	14	19	174
		0	0
Total of tubers	1,113	767	1,083
Surface shoots	82	76	17

TABLE XVIII.

Test digging in the Empress Gardens plots in weeded and hoed areas. Taken on 15-6-23 (in the middle) and on 26-10-23 (at the end) of the Experiment.

Plot No.	Operation	Digging on dates	Surface shoots	Total tubers	Total of normal tubers	Total of empty tubers
1	Weeded ..	15-6-23	11	295	215	80
		26-10-23	1	213	17	196
2	Control ..	15-6-23	344	952	941	9
		26-10-23	235	813	790	23
3	Hoed twice a week ..	15-6-23	35	475	463	12
		26-10-23	5	190	19	171
4	Hoed once a week ..	15-6-23	28	454	448	6
		26-10-23	16	367	270	97
Digging in an area less infested than the control plot II	..	15-6-23	40	280	271	9
		26-10-23	143	404	301	103

The net result again is this :—

Thorough weeding does reduce the number of shoots and tubers, but takes a long time and must be continuous.

By itself, weeding, even if very careful and continuous, can hardly be looked on as a method of extirpation in a badly infected area.

Experiments in the effect of cover :—

The next series of experiments deals with the effect of cover on the life of the *lavala* weed.

5. *Experiments in the effect of artificial cover.*

Experiment XXIX.

In Ganeshkhind Botanical Garden, in the vine plantation, where the ground had recently borne a cucurbit crop for the purpose of keeping down weeds, a plot 18×19 ft. was covered with bamboo matting on December 13, 1921. A similar plot was taken as a control. Test diggings showed no tubers in the second or third foot of soil in either case. In the first foot of soil in an area 3×3 ft. surface the number of tubers in the plot to be treated was 10 and in the control 15. This number is low, showing some effect probably of the cucurbit crop and previous cultivation. No water was given to either plot. On January 24, 13 shoots had pierced the matting. Several thicknesses of newspaper were therefore pasted over the matting. Once a month from February 1, onwards the plots were examined. The thirteen shoots became sickly, bent and shrivelled and no further germination occurred in either plot. Two test diggings in each plot were taken on September 7, 1922 after 11·78 inches of rain had fallen. The bamboo matting had to some extent kept out this rain. The control had a growth of other weeds, but neither showed *lavala*. The results of digging the usual 3×3 ft. pit were,

Covered plot. First foot 8 normal and 3 empty tubers,

Control, first foot 18 normal and 9 empty tubers.

This experiment was abandoned as a worse infested plot was required to give significant results. The only possible conclusion that can be drawn is that the cucurbit crop had adversely affected the tubers.

Experiment XXX.

On the College Farm an area 10×10 ft. was covered by bamboo matting on 13th December 1921. The area was isolated from the surrounding land by digging a trench round it 3 ft. deep and 1½ ft. broad. This incidentally

allowed us to get a measure of the density and distribution of the tubers in the soil of this part of the field. Table XIX shows this density and distribution. The plot was very badly infected and is in marked contrast to the Ganeshkhind Garden plot in the last experiment which we must consider as nearly free from the weed. On January 24, 1922, it was found that 23 shoots had pierced the matting. Several thicknesses of newspaper were then pasted over the matting. On February 10, shoots were appearing below the matting but were yellow and bent. On April 7 shoots were found issuing from the sides of the surrounding trench. The sides of the trench were then covered with matting. On May 4, it was found that shoots were piercing the matting on the sides of the trench. The trench was therefore filled up on that date. On September 1, one corner of the covered area measuring 1×1 ft. was dug out to a depth of 3 ft. No tubers were found in the third foot and a total of 100 tubers in the upper 2 ft. All were normal except those in the top 3 inches. These 100 tubers were planted in good soil at 3 ft. deep in Modi Bag and watered. By the end of September 40 had germinated. The period of covering (nine and a half months) was therefore clearly insufficient to kill the tubers beneath the cover.

TABLE XIX.

The number of tubers in the trenches around the area under cover of the matting.

Trench No.	Area of the trench	Shoots on the surface	TUBERS AT DIFFERENT DEPTHS			TOTAL
			In the first foot	In the second foot	In the third foot	
1	$10' \times 1\frac{1}{2}'$	335	730	420	40	1,525
2	"	410	921	514	74	1,919
3	"	380	678	284	56	1,398
4	"	217	442	204	45	908

Another test digging of the same kind was done on February 27, 1923, and the tubers similarly tested for germination. From the 18 to 24 inches depth only six tubers were got and none of these germinated. Above 18 inches tubers were numerous (total 829, of which 462 were not empty) from each 6 inches layer 40 were taken and put to germinate. Between March 10 and April 23, tubers from the top 6 inches germinated to the extent of 36 out

of 40, tubers from the second 6 inches to the extent of 32 out of 40. In April 1923 an iron sheet 10×4 ft. was laid on the soil near the plot covered by matting. In June a test digging revealed the fact that almost all tubers were plump and healthy. The sides of the sheet were then earthed up. Nevertheless, throughout the rains, shoots were being produced beneath the iron sheet. These were naturally etiolated. When the area was finally dug up it was found that many of the original old tubers were empty. The lavalá plants round about the covered area had sent in tubers under the iron sheet at about the six inches level. Table XX gives a comparison of the results as shown at the June test digging. The much reduced number of tubers in the middle of the matting cover shows that, at the side of the covered block of earth, air, light and infection from outside had all conspired to keep the tuber number high, while in the less favourable conditions in the centre of the matting the tubers were gradually being reduced. This, however, was after three months continuous cover.

TABLE XX.

*Test diggings (3'×3') in the area covered with matting, College farm,
June 12, 1923.*

Locality of the test digging	Date	Surface shoots	TUBERS AT DIFFERENT DEPTHS								Total of normal tubers
			0-6"		7"-12"		13"-18"		19"-24"		
			Empty	Normal	Empty	Normal	Empty	Normal	Empty	Normal	
Matting —											
N. W. Corner ..	12-6-23	0	155	556	105	109	112	201	2	10	876
S. W. Corner ..	"	2	219	314	119	109	25	41	4	2	470
Centre ..	22-6-23	2	224	55	243	56	3	0	0	0	111
Under the iron sheet ..	12-6-23	149	0	315	12	240	1	120	0	17	1,192
Control from a harrowed plot ..	"	12	15	739	0	221	3	107	0	11	1,078

The area, which had been under the bamboo matting, was exposed to the sun from July 27, 1923. Within a week shoots appeared on the surface near the edges. Three test diggings were made to ascertain the nature of the surviving tubers on August 8 and 14, 1923. Table XXI gives the results. The tubers from the third digging were transplanted to test viability. The

following is the result (Table XXII). The time of germination was from August 8 to October 31.

TABLE XXI.

Test diggings in the area under the matting cover, College Farm, Poona.

No. of pit	Date	Total of good tubers	TUBERS IN THE DIFFERENT LAYERS UP TO :—									
			6"		1'		1½'		2'		2½'	
			Normal	Empty	Normal	Empty	Normal	Empty	Normal	Empty	Normal	Empty
I	14-8-23	200	30	143	81	20	47	67	34	3	8	6
II	"	127	6	14	55	113	46	69	19	61	1	9
III	8-8-23	95	11	36	30	23	28	10	17	8	9	4

TABLE XXII.

Germination of the transplanted tubers.

1	Tuber out of	11	from the	6"	depth.	9.9	per cent.	Germination.
3	Do.	30	" "	1'	"	10.0	" "	"
5	Do.	28	" "	1½'	"	18.9	" "	"
8	Do.	17	" "	2'	"	47.0	" "	"
0	Do.	9	" "	2½'	"	0.0	" "	"

Later, on October 29 and 31, 1923, two dense patches of the weed that had arisen on the area after the removal of the bamboo matting were dug out and examined. The shoots were found to proceed from tubers below 18 inches deep. The upper tubers were dead. The total number of tubers was 247 (in the usual test digging of 3 × 3 × 3 ft.) of which 114 were empty, 23 normal solitary and 110 normal in chains. New tubers had been produced below 18 inches.

The general conclusion from these experiments is that cover is a very ineffective means of dealing with the tubers. Below 18 inches the original tubers may survive for more than two years and at that depth new tubers may be formed.

Experiment XXXI.

Pabco mulch is a specially prepared and waterproofed paper which is spread on land to keep down weeds and conserve moisture.

The paper was applied to land containing the *lavala* weed in the following ways :—

1. A square of 3 × 3 ft. was dug to three feet deep and cleaned of tubers. 100 tubers were then planted in the top six inches. *Pabco* mulch was laid on the top and firmly secured by earthing up the sides.

2. Another 3×3 ft. area was weeded so as to remove the surface shoots but leave those just about to appear. On this area the paper was laid.

3. In another 3×3 ft. area the paper was laid on the plants as they were. All these three plots were unirrigated.

4. A sheet of Pabco was laid on the earth of a water channel so as closely to cover the weeds and allow water to run over the paper.

5. An irrigated area 5×3 ft. was covered.

6. An area 20×3 ft. was covered and irrigated after laying down the paper.

These experiments were laid out on September 7, 1923. By September 17, 1923, in every one of these experiments the lava shoots had pierced the paper, formed basal bulbs and developed normal aerial parts. Adult leaves which had been covered had suffered, but the spearheads of the new shoots were quite sufficiently rigid to penetrate the cover.

Experiment XXXII.

At the Government Farm, Surat, a plot 10×10 ft. showing 25 lava shoots was covered by cut grass on February 21, 1922. This grass was allowed to stay on the ground till May 22, 1923. During this period the grass pile which was originally five feet high settled down to about three feet and received the monsoon rain, thereby becoming rotten. Lava shoots managed to come through the edges of the cover. A small part of the cover was removed and a test digging made on August 18, 1922, and again when the grass was removed. (Table XXIII.)

TABLE XXIII.

Test diggings from	Date	TUBERS	
		Normal	Empty
A. Covered area	Aug. 18, 1922	6	1
	May 22, 1923 (mean of three)	0	10
B. Control outside covered area ..	Aug. 18, 1922	43	35
	Dec. 29, 1922 (mean of three)	172	117
	May 22, 1923 (mean of three)	89	0

In this case the cover has certainly killed the tubers.

Experiment XXXIII.

At the Government Farm, Surat, near the area of the last experiment, another plot of 10×10 ft. was covered to a depth of six feet by cotton stubble. This pile settled down to about five feet and was penetrated at its edges by laval shoots. The cover was removed on May 22, 1923.

In this case also all the tubers in three test diggings were empty.

In both experiments the top soil up to six inches deep from the surface beneath the cover had dried, but the layers below had a good deal of moisture.

Experiments in the effect of Agricultural Operations.

The next series of experiments deals with the effect of agricultural operations in the field on the weed.

Experiment XXXIV.

At the Government Fodder Farm, Nadiad, a plot 66×66 ft. was ploughed and harrowed, and the number of tubers brought to the surface counted. An idea of the original density of the tubers in this plot was got by two test diggings, of which the figures are in Table XXIV.

TABLE XXIV.

NADIAD.

Test Diggings before the operations.

I. PLOT TO BE PLOUGHED—(average of two test diggings).

	First foot	Second foot	TOTAL
Tubers in	222	43	265

II. CONTROL PLOT—(average of two test diggings).

	First foot	Second foot	TOTAL
Tubers in	191	13	204

All these are healthy tubers.

TABLE XXV.

Test Diggings after the operations.

I. PLOUGHED PLOT—(average of three test diggings).

	On surface	First foot	Second foot	TOTAL
* Tubers	52	147	104	303

II. CONTROL PLOT—(average of three test diggings).

	First foot	Second foot	TOTAL
Tubers in	48	75	123

The operations were as follows :—

December 14, 1921. Ploughing to seven inches deep with a BT2 plough.

December 16, 1921. Breaking of clods by hand with hammers.

December 20, 1921. Disc harrowing.

February 12, 1922. „

February 26, 1922. „

March 12, 1922. „

March 27, 1922. „

March 30, 1922. Second ploughing to seven inches with BT2 plough.

April 13, 1922. Disc harrowing.

April 17, 1922. „

The farm was closed in May, 1922.

During the experiment the total number of tubers brought to the surface in an area of 3×3 ft. (average of two such areas) was 170.

Final test diggings were taken on May 25, 1923, and are given in Table XXV.

The plot was revisited in August 1922. Lavalas shoots were present in the plot and were found to be coming mainly from tubers in the second foot of soil.

* Tests showed that of the tubers on the surface all were dead and from the next six inches 70 per cent. were dead in the ploughed plot. This reduces the actual living tubers in the first plot to 203.

In this experiment, however, we can see that a greater number of test diggings should have been averaged to get reliable comparative results. What we do learn is that agricultural operations bring to the surface a great number of tubers and that these die.

6. *Experiments in the competition of other plants with Cyperus rotundus.*

The next set of experiments deal with the competition of other plants with *lavala*.

*Experiment XXXV.*Effect of Grasses on *Lavala*.

Several observations indicated that it might be possible to smother *lavala* by grasses. Some such indications were as follows :—

- (1) Near canals in fields where *lavala* was growing it was absent from patches of hariali grass (*Cynodon dactylon*).
- (2) At Khandala, Lonavala and Karjat, *lavala* abounded in the rice fields but was absent from the adjoining grass lands.
- (3) At Surat Farm an experiment in growing wild fodder grasses gave hopes of smothering *lavala* by this method.
- (4) In Gujarat it is a well known practice to leave very badly *lavala* infested fields fallow for a number of years. Grass grows on such fields and the *lavala* dies out. The fields are then again taken into cultivation.

On the other hand, however, in the polo ground of the Willingdon Sports Club in Bombay and in the Gardens of the Bombay Improvement Trust, *lavala* was found growing amongst hariali grass in sufficient quantity to be regarded as a pest. In both cases it is believed that the tubers were brought in from the race course with horse manure stacked there,—the *lavala* being present in that area.

The following eight experiments were accordingly arranged :—

- (1) Isolated tubers were planted on a lawn in the bungalow compound of Dr. Burns, Economic Botanist, Poona. This lawn was practically pure *Andropogon annulatus* and *A. caricosus*.
- (2) Tubers were planted in grass areas adjoining the Karjat Rice Experiment Station.
- (3) Tubers were planted in the lawns of the Improvement Trust Garden, Bombay. The grasses there were hariali (*Cynodon dactylon*) and heda (*Paspalum distichum*).
- (4) Tubers were planted amongst heda grass in Modi Bag in the College of Agriculture, Poona, and heda grass was planted amongst *lavala* in the College Farm.
- (5) The effect of natural invasion of hariali on a *lavala* plot was observed on the College Farm.

Experiment XXXVI.

Planting of isolated tubers in the Economic Botanist's lawn.

The lawn was divided up by paths radiating from the centre, into seven triangular sections. The lawn was flooded with canal water once in ten days except during the rains. One metre quadrat was taken in each sector and one big selected tuber planted three inches deep in the centre of each quadrat, on 19th August, 1922. By 28th August the tubers in five quadrats had germinated (1, 2, 3, 5 and 6). They did not, however, produce any more shoots or tubers up till 23rd November 1922. The grass was then cut. Fresh tubers were then planted in all the quadrats except the third and fifth where the shoots were still alive (the tubers in 1, 2 and 6 having died). On 31st April, 1923, the tubers of the second planting in quadrats 6 and 7 had one shoot each. All the others were dug out and found to be empty and dead. A third planting of tubers in the same quadrats was then done on 31st April, 1923.

On June 16, 1923, it was found that the tubers in quadrats 3 and 5 from the previous planting had produced one tuber each and had died and the tubers in 1, 2 and 6 had produced straggling shoots which were withering and the tubers in 4 and 7 were dry and shrivelled. A fourth planting was done after digging out these tubers on June 21, 1923, and five tubers were planted in each quadrat area. These had the benefit of the rains, but the grass also grew thick and an observation taken on October 29, 1923, shows that only one tuber had germinated out of the whole lot of 35 tubers.

This shows that the tubers were unable to produce more growth in a soil already full of grass roots and that the dense cover on the surface prevented vigorous aerial growth.

Experiment XXXVII.

Planting of tubers in grass areas adjoining the Karjat Rice Experiment Station.

Five quadrats were marked out on a slope full of grass on the west of the present office building at Karjat.

- | | | |
|---------|---------|--|
| Quadrat | I. | Grass undisturbed (control plot). |
| " | II. | 100 tubers from Poona fields were planted in a grass plot. |
| " | III. | 100 tubers from Karjat rice fields were planted in a grass plot. |
| " | IV & V. | 100 tubers were planted in a grass plot from which the grass had been weeded (IV and V were duplicates). |

The tubers were planted in all the quadrats on 22nd August, 1922, and the conditions were favourable as rain was falling at the time.

The tubers from Poona were transported in wet gunny bag material and hence there was no fear of their drying out before planting.

These quadrats were again examined on 6th December, 1922. Observations :—

- I. Grass normal.
- II. Only seven tubers had germinated out of the 100. The shoots were weak.
- III. Twelve tubers out of 100 had germinated.
- IV. Fifty-four out of 100 had germinated.
- V. Sixty-six out of 100 had germinated.

Out of these plots IV and V, however, with their total of 120 germinated tubers, only 30 shoots were green at the time of observation. Out of these again four only had produced small tuber colonies of 6, 3, 5 and 6 tubers respectively.

The quadrats were again observed on 6th April, 1923. Observations :—

- I. Grass dry.
- II. All the tubers shrivelled. They were dug out.
- III. Three laval plants were alive, of which two had four and two tubers respectively.
- IV and V. Dried shoots of 20 plants were found in these two taken together, and in the soil 50 dormant healthy tubers. The living plants and the 50 dormant tubers were replaced in the same quadrats.

The quadrats were finally observed in August 1923. Observations :—

- I. Grass thick.
- II. Grass thick. No laval visible.
- III. Grass thick. No laval visible.
- IV and V. Grass thick. No trace was found of the plants and tubers replaced in these quadrats.

This preliminary experiment shows that in grass land on the slopes of this hill the soil conditions were unfavourable to this plant and the thick matting of the fibrous grass roots gave little scope for the laval tubers to sprout, root and multiply. In the weeded plots the laval got a footing and only the uprooting of the tubers stopped their growth.

Experiment XXXVIII.

Planting of tubers in the lawns of the Improvement Trust, Bombay.

Two quadrats in a hariali lawn were laid down and 50 *lavala* tubers planted on 24th August, 1922. At the same time 40 *heda* grass stumps were planted in the same quadrats, without removing the existing hariali. There were already at the time of planting on quadrat—

I. *Lavala* shoots 56.

II. „ 49.

The lawn was mowed on 12th September, 1922, and 21st September, 1922, and on September 24, the position was—

Quadrat I. *Lavala* shoots 82. *Heda* stumps 40.

„ II. „ „ 65. „ „ 39.

The place was again observed on 6th December, 1922. The stumps were unaltered in number but were dry and stunted. The *lavala* shoots were (I) 30 and (II) 27 respectively. *Hariali* was growing thickly on both quadrats. On the same day both quadrats were dug out and the tubers were counted. Results :—

TABLE XXVI.

	Shoots	TUBERS	
		9-12"	12-18"
(1) Control test digging at the time of planting (24-8-22)	60	120	80
(2) Control test digging at the time of digging out the quadrats (6-12-22)	30	189	100
(3) Quadrat I	30	150	50
(4) „ II	27	139	25

The soil was one and a half feet deep over sand. The tubers dug out were all plump and dormant.

In this experiment there is evidence of a smothering effect by the grass especially in reducing the number of deep-lying tubers. This experiment was then discontinued. The control test diggings both on 24th August, 1922, and 6th December, 1922, were done on areas of the same surface size as the experimental quadrats and on ground near to them. These diggings indicate that the *lavala* although somewhat reduced was existing along with the *hariali* and that it was vigorous.

The fact that the lavalas grew well along with the hariali may have been due to the fact that the lawn was comparatively newly made with imported earth.

In another quadrat (III) the soil was dug up to six inches deep and the original lavalas and hariali removed on 24th August, 1922. Heda grass was planted on the same date in the plot along with 50 tubers of lavalas. The grass grew vigorously. Out of the 50 tubers 30 had germinated by 6th December, 1922.

In still another quadrat (IV) 50 tubers were planted in a plot prepared like III by digging to six inches deep, but no grass was planted along with the tubers on 24th August, 1922. 42 out of the 50 germinated by 6th December, 1922. Both these quadrats were dug out on 6th April, 1923. The following is the result:—

TABLE XXVII.

					Shoots	TUBERS	
						0-12"	12-18"
Quadrat	III	..	..	..	35	35	10
..	IV	..	..	..	93	122	20

The soil in these two quadrats had been recently deposited and was underlaid by sand. Here the heda grass had had a distinct effect on the vigour of growth of the lavalas though it had by no means checked it.

Experiment XXXIX.

Planting tubers in Modi Bag amongst grass.

On 19th September, 1922, eight metre-quadrats were prepared. These were sited in an unirrigated area already naturally infested with lavalas. 100 heda stumps were planted in each quadrat. The number of tubers in the adjoining test digging were—

Shoots	First foot	Second foot
236	257	120

The quadrats were watered twice a week for about a month. Thereafter there was no irrigation. Table XXVIII shows the number of shoots of

lavala and of living heda stumps (at the time of planting and on November 23, 1922) :—

TABLE XXVIII.

Quadrat No.	LAVALA - SHOOTS		HEDA STUMPS	
	Dates		Dates	
	19-9-22	23-11-22	19-9-22	23-11-22
1	185	258	100	86
2	276	382	100	72
3	319	438	100	45
4	215	316	100	62
5	263	304	100	69
6	320	373	100	46
7	277	384	100	23
8	314	815	100	24

The heda stumps died for want of irrigation and lavala completely filled the quadrats.

On 19th September, 1922, 500 heda stumps were planted in two small strips 8×2 and 6×2 ft. at right angles to one another near a small tank in Modi Bag. This grass thoroughly established itself. On 11th October, 1922, 36 lavala tubers were planted 20 in one arm and 16 in the other arm of the L. They were planted at regular intervals at three inches deep. On 20th November, 1922, 47 lavala shoots were visible, 32 in the one arm and 15 in the other, and 525 heda stumps (342 and 183 respectively).

One lavala plant from near the side of the grass plot was dug out. It was found that the original tuber had produced one shoot and a chain of three tubers, growing horizontally. The last two tubers were just outside the grass patch and were sprouting. On 10th July, 1923, the plot had 75 shoots of lavala (40 and 35) and the heda clumps were very dense.

Both the strips were dug out in September, 1923, when the soil was workable. The heda clumps were very dense and only (30 and 20) 50 lavala shoots were seen on the surface. But of the original 56 tubers planted three inches deep only 35 were found to be sprouting at that time. The others were empty.

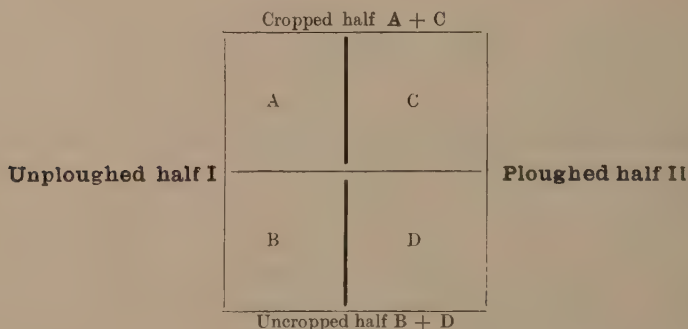
The rooting of the grass was not deeper than four inches. But chains of big tubers were found beneath the six inches layer lying horizontal between six to twelve inches, sometimes coming out the covered area and producing shoots. 106 such tubers were found.

We have here a clear indication of the tactics of the lavalva plant in competition with other plants. The lavalva struggles to put up an aerial connection, wherever possible. From tubers so connected it sends off droppers to layers unoccupied by the roots of the competing plants, there it stores food material and from them or from the original tubers it sends off horizontal rhizomes to explore for places outside the dense competing aerial cover where it may send up shoots more successfully.

Experiment XL.

7. Experiments on the Effects of Cultivation and Cover Crops.

The field chosen for this experiment was on the Government Farm, Surat, and carried a crop of jowar from June to November 1921. Test diggings of the usual dimensions ($3 \times 3 \times 3$ ft.) were taken before the start of our experiment and showed a dense tuber population. The plot was divided into two areas and the first was left untreated, while the second was submitted to the agricultural and cultural operations shown in table XXIX. These continued till August 1922, when in each area one half was sown with jowar and the other half left as a control. The following sketch will make the position clear.



The sowing of jowar on the first area meant that half of it had to be lightly ploughed before sowing.

Test diggings were taken throughout the experiment and these are recorded in table showing the changes in the tuber population. After the jowar was harvested, the original area II containing the C and D sub-plots was again thoroughly and continuously cultivated until the following June.

TABLE XXIX.
Combined Experiments at Surat on the Effect of Cultivation and a Cover Crop.
AREA I.

Date of test digging	Operations between test diggings	TUBERS FOUND AT EACH TEST DIGGING		Operations between test diggings	TUBERS FOUND AT EACH TEST DIGGING		REMARKS
		Normal	Empty		Normal	Empty	
12-12-21	None	471	0	None	546	0	Dense healthy tuber population in all plots
24-4-22	None	509	0	Gallows ploughed, Norwegian harrowed. Disc harrowed	405	10	A little improvement in the ploughed plot
30-5-22	None	175	0	Tooth cultivator worked	135	0	Marked drop in tuber population, of all plots, probably effect of hot weather; fewer tubers in ploughed plot
28-8-22	None	3 (Average two diggings)	141	None	1	51	Deaths of tubers in all plots probably due to continued hot weather; fewer tubers in ploughed plots

5-6-23	None (additional Test diggings at junction of A & B plots)	178	40	57	4	Gallows plough- ing once: B r o a c h plough twice weekly (ad- ditional test digging at junction of C & D plots)	0	91	0	118	In A & B plots the lavala is rapidly regaining its hold. In C & D it is extirpated.
		Normal 69		Empty 6				Normal 0		Empty 151	

A study of the Table XXIX along with its remarks column brings out the following points.

(1) In both areas the lavalva had a bad time in the hot weather of 1922, the rain, however, revived it considerably and until the crop was harvested we cannot say that there was a very striking difference between the area which had been ploughed in the preceding hot weather and that which had not, although there is undoubtedly a reduction of the tuber population in the area ploughed.

(2) The effect of the cover crop in both areas on reducing tuber production, taken against the control plot in its own area, is negligible. In fact the figures give a less tuber viability for the sub-plots without the cover crop.

(3) The cultivation in the second hot weather has, however, been absolutely effective as the figures amply show. The untreated area (both A and B) has a large tuber population (not however anything like equal to its first condition) with a large percentage of viable tubers, while the treated area (C and D) has not a single living tuber left.

This is the most conclusive proof we could have of the value of *continuous* thorough cultivation in the hot weather. It indicates also that the battle may not be won in the first hot weather cultivation but should be won for certain if the same process is continued for a second hot weather after one rains crop.

An experiment similar to the above in which only a harrow was worked was carried out. Mere harrowing proved entirely ineffective as the deeper tubers were untouched.

Experiment XLI.

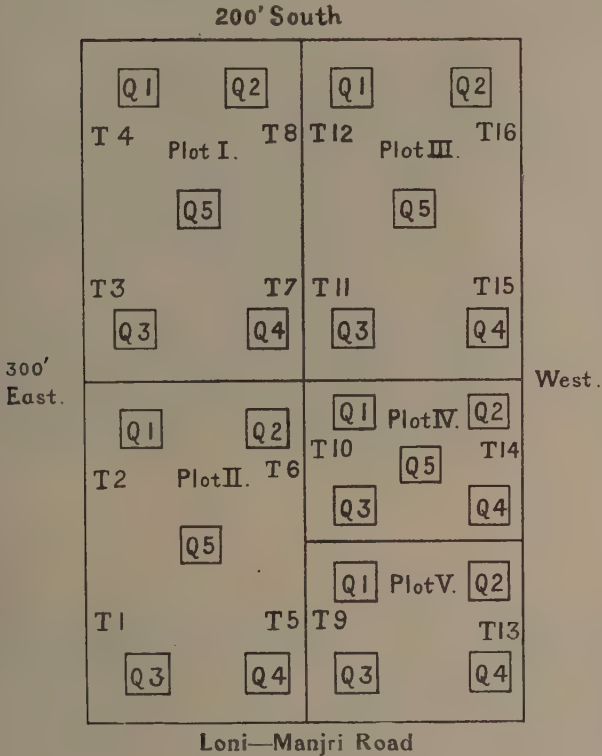
At Manjri near Poona in the vicinity of our sugar station we leased a piece of land badly infested with lavalva. This area was 300 by 200 ft. in size and was divided into five plots.

Plots I, II and III were sown to a cover crop, plot IV was an absolutely undisturbed control and plot V was ploughed once in the beginning.

Test diggings (3×3×3 ft.) were taken in each plot at the points marked T 1 to T 16.

The middle of the plot was worse infested than either edge. The eastern edge was probably affected by the shade and the roots of trees along that side. No tubers were found below 18 inches, the subsoil being shadu (chalky soil) or murum. The average distribution taking the average of all the diggings was 154 per digging of 3×3×3 ft., of the eight middle diggings 234, and of the eight diggings on the East and West edges 74.

*Effect of cover on Lavala Plan.
Cover crop experiment at Manjri.*



T. Test digging in the beginning of the experiment.

Q. Quadrat area on which the Lavala and sann plants are counted once every fortnight.

Plot I, II, III were under cover. Plot IV control untreated. V control ploughed once.

Treatment.

Plots I, II and III were ploughed in June 1923 by an iron plough. The rains were late. Sann hemp was sown at the rate of 30 lb. per plot of 150 by 100 ft. in July 1923. From August 1, weekly observations were taken to get some idea of the growth of the sann hemp and of the lava. For this purpose five fixed quadrats were laid out (labelled Q1 to Q5) in each plot. The number of lava shoots and sann hemp plants was counted in each quadrat. On September 4 and 5 irrigation was given as the sann was growing poorly, especially near the middle of plot I. Six additional quadrats were

also laid out in dense sann growth on September 15 and counted once. The sann hemp was cut and ploughed in on October 8, 1923.

Plate VIII (1) shows the ploughing in progress. The bunch of sann hemp held by the woman indicates the growth of the cover crop. Plate VIII (2) shows the lavalas among the cut sann hemp. Such shoots had etiolated leaves from 8 to 12 inches long.

The total amount of sann hemp buried for plots I, II and III taken together was 5,700 lb.

Table XXX shows the results of the countings on the quadrats.

TABLE XXX.
Table of averages.

Plot No.	Average No. of lavalas shoots per quadrat	Average No. of sann shoots per quadrat	Average height of sann (ft.)	Product of last two columns
I	153.8	133.2	3	399.6
II	90.0	104.0	2	208.0
III	110.2	164.2	3.5	574.7
IV	173.6	Not ploughed, no sann hemp		
V	17.2	Ploughed, no sann hemp		

Points to note :—

Where sann hemp is poor in growth lavalas makes headway.

Ploughing and exposure by itself (plot V) has been more effective as to shoot reduction than sann hemp sowing.

The untreated plot IV was by far the worst.

When we come to consider tuber reduction, however, the sann hemp treatment easily wins. Table XXX(a).

TABLE XXX(a).

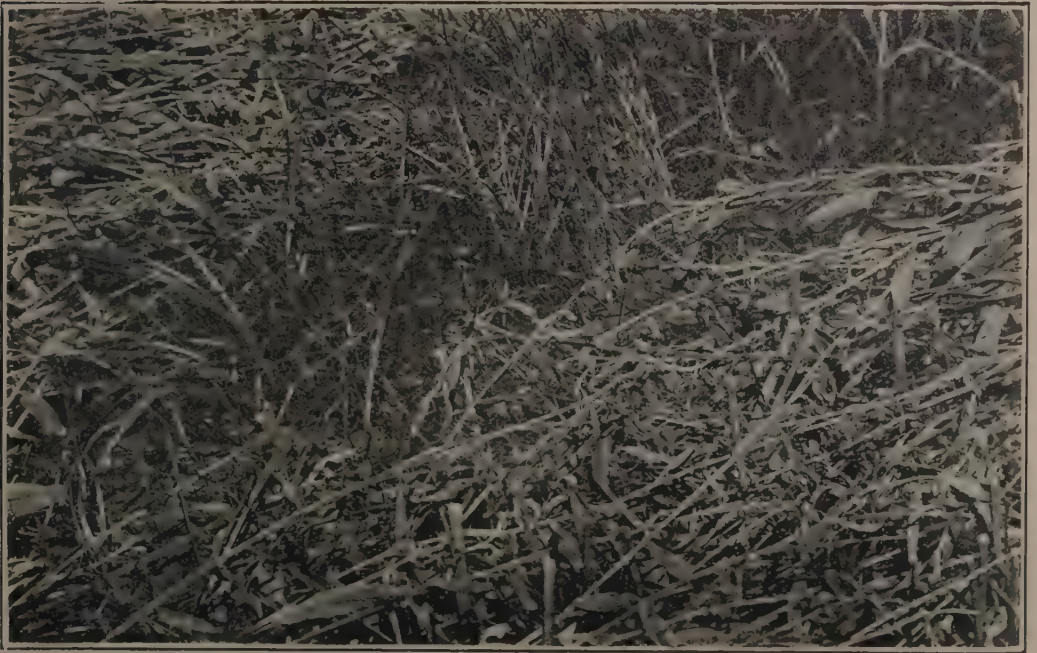
Effect of Sann hemp and ploughing on tuber population.

Plots I, II and III taken together (average of fifteen test diggings)				..	Number of tubers in 3×3×3 ft.
Before treatment				..	241 all sound
After treatment ..				..	160 of which 40 were dead
Plot IV (undisturbed control) average of five test diggings					
At start of experiment				..	251 all sound
At end of experiment				..	557 all sound
Plot V. (Ploughed control) average of five test diggings					
Before treatment				..	158 all sound
At end of experiment				..	228 all sound.

Ploughing and exposure in this case has *not* reduced the tuber population. The reason is that the exposure occurred in the rainy season,



1. Ploughing in progress. The bunch of sann hemp held by the woman indicates the growth of the cover crop.



2. Lavala among the cut sann hemp.

V. GENERAL CONCLUSIONS.

- * "Hundreds of other opportunities could be suggested. Almost any insect or plant disease that is limited to a single host or presents a vulnerable point in its life history extending through a sufficiently long period of time to give the possibility of control may be considered as a possible candidate for eradication whenever a scientific investigation has progressed to such a point as to give the tools necessary for its accomplishment."

The above quotation can with equal truth be applied to weeds, and we propose now to examine how far the scientific investigations recorded in the preceding pages have provided the tools necessary for the eradication of the lavalá weed.

The lavalá weed, we have seen, is cosmopolitan in warm countries and is a weed of cultivation, particularly of irrigated fields. Salt and inundation destroy it, but as salt is injurious to other plants and inundation is important only in rice fields, these two methods of control can be left out of account at present.

The first important contribution to our equipment for eradication is the better understanding of the structure and life history of this weed. Let us briefly go over the main points established.

The plant as it occurs in the field is a colony of many tubers connected by underground rhizomes and distributed throughout the first three feet of soil. On the surface are its aerial shoots whose number bears no necessary relation to the number of subterranean tubers. Throughout the year and particularly in July and October, flowers are produced which result in the production of small fruit ("seeds"). The viability of these is exceedingly variable, from one to eighty per cent. according to circumstances. The number of seeds produced, however, is so enormous (calculated at fifty-four million seeds per acre), that even with a small germination percentage, seed production will obviously be an effective means of reproduction.

THE PREVENTION OF SEED PRODUCTION IS THEREFORE OF
IMPORTANCE.

The germination of the seed and development of the seedling have been studied. In this plant we have an extreme example of the geophilous habit,

* Research Work of the Department of Agriculture, by E. D. Ball, Director of Scientific Work, U. S. Department of Agriculture, in the *Chemical Age*, article copied in full in the *American Fertilizer*, Jan. 26, 1924, pp. 62-68.

whereby a plant immediately after establishing its first aerial connection devotes all its energy to producing a subterranean tuber or tuber-system, to escape climatic changes above ground. In the case of both seed and tuber germination and development we have found that *unless the seed or tuber can establish an aerial connection it cannot produce a tuber or tuber-system.*

The next indication of importance therefore is—

GERMINATING SEEDS OR TUBERS MUST BE PREVENTED FROM
ESTABLISHING AN AERIAL CONNECTION.

If a seed or a tuber succeeds in establishing this aerial connection we find that it develops a "basal bulb" at the place where the aerial leaves join the stem and from this bulb in the case of the seedling or tuber-plant, and from the parent tuber as well, in the case of the latter, new rhizomes are then developed. In the seedling these rhizomes produce tubers, while in the case of the tuber plant they may form new aerial shoots as well as tubers. In many cases these new rhizomes are of the nature of "droppers," that is, positively geotropic rhizomes whose business it is to penetrate still deeper into the soil and there establish new bases more protected than the shallow-lying tubers. These tubers may in turn give rise to more rhizomes, and we soon have a tuber colony of considerable size.

The eradication of an established laval colony is therefore a matter of very great difficulty. In the first place, in normal circumstances, all the tubers are viable. Drought may kill the superficially placed tubers, but the more deeply placed ones survive. Ordinary weeding touches only the very top tubers and normal ploughing and harrowing deals with the top foot of soil at the most. How then are we to deal with a thoroughly established colony?

OBVIOUSLY, BADLY INFESTED LAND MUST BE CLEARED AT ALL COSTS
AND THEN KEPT FROM FURTHER INFECTION.

The first step is the clearing.

In this connection we have studied the various methods for killing tubers. It has been found that although tubers can be found at three feet deep in the soil in a tuber system, isolated tubers buried at that depth or even at $2\frac{1}{2}$ ft. deep usually cannot produce a shoot that will reach the surface.

WE THEREFORE GET SOME HOPE THAT, IF ALL SUPERFICIALLY PLACED TUBERS CAN BE DESTROYED, AT LEAST SOME OF THE DEEPLY PLACED TUBERS WILL NOT BE ABLE TO PRODUCE SHOOTS WHICH WILL REACH THE SURFACE.

Again, theoretically, one would expect that the repeated removal of the aerial parts would result in the exhaustion of the reserve material in the tuber. In the case of isolated tubers this has been found possible, though even then the

APPENDIX.

INCUBATOR EXPERIMENT.

TABLE XXXI.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 93·2°F. (34°C.).

Date of heating, 10th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	9.25	8.01	10.742	8.272	8.072
Weight of 10 tubers. after heating	8.88	7.80	10.380	8.000	7.760
Loss in weight	-0.37	-0.21	-0.362	-0.272	-0.312
Percentage of loss in weight ..	-4.00	-2.62	-3.460	-3.300	-3.860
Placed in a wet soil for 24 hours					
Weight after absorption of water ..	9.945	8.481	11.350	8.65	8.390
Change in original weight ..	+0.695	+0.471	+0.608	+0.37	+0.318
Change in heated weight					
Date of planting in soil two inches deep and watered ..	16th August, 1921				
Observations regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated ..	9	8	8	9	7
Percentage of germination ..	90	80	80	90	70

the paramount importance of cultivation and particularly of continuous hot weather cultivation makes itself strikingly evident.

In fine, the results reduce themselves to this—

THE WEED MUST BE ATTACKED IMMEDIATELY AFTER THE RAINS AS SOON AS THE SOIL IS WORKABLE. THE PROCESS SHOULD INCLUDE DEEP PLOUGHING AND A SUBSEQUENT PULVERISATION AND TURNING OVER AND OVER OF THE BROKEN SOIL IN ORDER TO EXPOSE AS MANY TUBERS AS POSSIBLE TO THE SUN.

IF THE LAND IS NOT WANTED FOR A CROP IN THE FOLLOWING RAINS THEN A THICK GREEN MANURE CROP SHOULD BE GROWN AND PLOUGHED IN EARLY, FOLLOWING UP BY A SECOND DRY SEASON'S CONTINUOUS CULTIVATION. THE LAND SHOULD THEN BE CLEAR OF WEED.

IF THE LAND IS WANTED FOR A RAINS CROP, THE CROP SHOULD BE SOWN SO THAT INTERCULTIVATION CAN BE CONTINUOUSLY PRACTISED TO KEEP DOWN THE LAVALA SHOOTS AND PREVENT THE ESTABLISHMENT OF THAT AERIAL CONNECTION WITHOUT WHICH TUBER FORMATION IS IMPOSSIBLE. A SECOND DRY SEASON'S CULTIVATION SHOULD THEN REDUCE THE WEED, AND A THIRD SEASON'S WORK KILL IT.

Thereafter, there should be no difficulty in keeping the clean land from further infection.

APPENDIX.

INCUBATOR EXPERIMENT.

TABLE XXXI.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 93·2°F. (34°C.).

Date of heating, 10th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	9·25	8·01	10·742	8·272	8·072
Weight of 10 tubers. after heating	8·88	7·80	10·380	8·000	7·760
Loss in weight	—0·37	—0·21	—0·362	—0·272	—0·312
Percentage of loss in weight ..	—4·00	—2·62	—3·460	—3·300	—3·860
Placed in a wet soil for 24 hours					
Weight after absorption of water ..	9·945	8·481	11·350	8·65	8·390
Change in original weight ..	+0·695	+0·471	+0·608	+0·37	+0·318
Change in heated weight					
Date of planting in soil two inches deep and watered ..	16th August, 1921				
Observations regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated ..	9	8	8	9	7
Percentage of germination ..	90	80	80	90	70

INCUBATOR EXPERIMENT.

TABLE XXXII.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 98·6°F. (37°C.).

Date of heating, 9th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	9·74	10·96	9·94	8·640	9·57
Weight of 10 tubers after heating/	9·45	10·68	9·78	8·355	8·33
Loss in weight	-0·29	-0·28	-0·16	-0·285	-1·24
Percentage of loss in weight	-2·90	-2·50	-1·60	-3·290	-12·90
Placed in a wet blotting paper for 24 hours					
Weight after absorption of water	8·40	11·645	11·195	8·895	10·00
Change in original weight	-1·34	+0·685	+1·255	+0·255	+0·43
Change in heated weight					
Date of planting in soil two inches deep and watered	16th August, 1921				
Observations regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated	0	7	6	7	6
Percentage of germination	0	70	60	70	60
	These tubers had failed to regain the weight lost				

INCUBATOR EXPERIMENT.

TABLE XXXIII.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 104°F. (40°C.).

Date of heating, 4th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	10.045	9.991	9.750	9.82	10.670
Weight of 10 tubers after heating	9.750	9.702	9.527	9.53	9.352
Loss in weight	-0.295	-0.289	-0.223	-0.29	-1.318
Percentage of loss in weight ..	-2.090	-2.900	-2.280	-2.90	-12.300
Placed in wet blotting paper for 24 hours					
Weight after absorption of water ..	10.428	12.208	10.003	10.426	10.876
Change in original weight ..	+0.383	+2.217	+0.253	+0.606	+0.206
Change in heated weight ..	+0.678	+2.506	+0.476	+0.896	+1.524
Date of planting in soil two inches deep and watered	11th August, 1921				
Observation regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated ..	9	7	6	9	7
Percentage of germination ..	90	70	60	90	70

INCUBATOR EXPERIMENT.

TABLE XXXIV.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 110°F. (43°C.).

Date of heating, 3rd August, 1923.

Table of weights (grammes).

	DURATION OF HEATING				
	10 Minutes	20 Minutes	30 Minutes	1 Hour	2 Hours
Weight of 10 tubers before heating	10.45	9.580	10.642	9.750	8.950
Weight of 10 tubers after heating /	10.16	9.372	10.295	9.457	8.617
Loss in weight	-0.29	-0.208	-0.347	-0.293	-0.353
Percentage of loss in weight	-2.77	-2.190	-3.260	-3.006	-3.800
Placed in wet blotting paper for 24 hours					
Weight after absorption of water ..	10.76	10.506	10.980	9.330	10.490
Change in original weight ..	+0.31	+0.926	+0.338	+0.420	+1.540
Change in heated weight ..	+0.60	+1.134	+0.685	+0.127	+1.773
Date of planting in soil two inches deep and watered	10th August, 1923				
Observation regarding germination	Began to germinate from 20th August, 1923				
No. of tubers germinated ..	8	8	3	7	8
Percentage of germination ..	80	80	30	70	80

INCUBATOR EXPERIMENT.

TABLE XXXV.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 112.8°F. (46°C.).

Date of heating, 2nd August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	7.170	8.245	9.802	6.207	7.6
Weight of 10 tubers after heating	6.924	7.540	8.650	5.924	7.2
Loss in weight	-0.246	-0.705	-1.152	-0.283	-0.4
Percentage of loss in weight ..	-3.400	-8.500	-11.800	-4.500	-5.2
Placed in a wet blotting paper for 24 hours					
Weight after absorption of water ..	7.560	8.600	9.380	6.710	7.76
Change in original weight ..	+0.390	+0.355	-0.422	+0.503	+0.16
Change in heated weight ..	+0.636	+1.060	+0.730	+0.786	+0.56
Date of planting in soil two inches deep and watered ..	..	9th August, 1921			
Observations regarding germination	Began to germinate by 20th August, 1921				
No. of tuber germinated ..	6	8	7	10	8
Percentage of germination ..	60	80	70	100	80

INCUBATOR EXPERIMENT.

TABLE XXXVI.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 120°F. (49°C.).

Date of heating, 5th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING				
	10	20	30	1	2
	Minutes	Minutes	Minutes	Hour	Hours
Weight of 10 tubers before heating	9.47	10.67	9.570	9.128	10.450
Weight of 10 tubers after heating /	9.20	10.40	9.255	8.820	9.970
Loss in weight	-0.27	-0.27	-0.315	-0.308	-0.480
Percentage of loss in weight ..	-2.90	-2.50	-3.300	-3.300	-4.590
Placed in a wet blotting paper for 24 hours					
Weight after absorption of water ..	10.155	11.595	9.880	8.980	10.72
Change in original weight ..	+0.685	+0.925	+0.310	-0.148	+0.27
Change in heated weight ..	+0.955	+1.195	+0.425	-0.160	+0.75
Date of planting in soil two inches deep and watered	..	12th August, 1921			
Observations regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated ..	10	9	8	8	7
Percentage of germination ..	100	90	80	80	70

INCUBATOR EXPERIMENT.

TABLE XXXVII.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 112.8°F. (46°C.).

Date of heating, 2nd August, 1921.

Table of weights (grammes).

	DURATION OF HEATING (HOURS)				
	3	4	5	6	7
Weight of 10 tubers before heating	7.605	7.105	7.598	6.675	7.075
Weight of 10 tubers after heating ..	6.790	6.750	6.855	6.015	6.060
Loss in weight	-0.815	-0.355	-0.743	-0.660	-1.015
Percentage of loss in weight ..	-10.710	-4.990	-9.790	-9.890	-14.340
Placed in a wet blotting paper for 24 hours					
Weight after absorption of water ..	7.265	7.145	7.385	6.384	6.605
Change in original weight ..	-0.340	0.040	-0.213	-0.291	-0.470
Change in heated weight ..	+0.475	+0.395	+0.530	+0.369	+0.545
Date of planting in soil two inches deep and watered	16th August, 1921				
Observations regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated ..	4	0	2	1	1
Percentage of germination ..	40	0	20	10	10

INCUBATOR EXPERIMENT.

TABLE XXXVIII.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 120°F. (49°C.).

Date of heating, 11th August, 1921.

Table of weights (grammes).

	DURATION OF HEATING (HOURS)				
	3	4	5	6	7
Weight of 10 tubers before heating	7.550	8.628	10.940	7.798	8.573
Weight of 10 tubers after heating	6.965	7.982	9.884	7.059	7.340
Loss in weight	-0.585	-0.646	-1.056	-0.739	-1.233
Percentage of loss in weight	-7.740	-7.490	-9.660	-9.490	-16.800
Placed in a wet blotting paper for 24 hours					
Weight after absorption of water	7.770	8.745	10.825	7.870	8.340
Change in original weight	+0.220	+0.117	-0.115	+0.072	-0.233
Change in heated weight	+0.805	+0.763	+0.941	+0.811	+1.000
Date of planting in soil two inches deep and watered	16th August, 1921				
Observation regarding germination	Began to germinate from 20th August, 1921				
No. of tubers germinated	7	5	3	6	6
Percentage of germination	70	50	30	60	60

INCUBATOR EXPERIMENT.

TABLE XXXIX.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 104°F. (40°C.).

A. TUBERS PLACED IN PAPER DISHES WITHOUT EARTH.

Date of starting, 20th March, 1923.

Table of weights (grammes).

	DURATION OF HEATING (HOURS)			
	3	7	8	14
	I A	II A	III A	IV A
Weight of 10 tubers before heating ..	19.515	15.540	15.325	15.335
Weight of 10 tubers after heating ..	15.900	10.210	9.610	8.780
Loss in weight	-3.615	-5.325	-5.715	-7.555
Percentage of loss in weight ..	-18.520	-34.260	-37.290	-49.200
Placed in a wet blotting paper for 24 hours				
Date	23-3-23	27-3-23	28-3-23	4-4-23
Weight after absorption of water ..	18.130	12.42	12.200	10.800
Change in original weight ..	-1.385	-3.12	-3.125	-4.535
Change in heated weight ..	+2.230	+2.21	+2.590	+20.200
Date of planting in soil two inches deep and watered	24-3-23	28-3-23	29-3-23	5-4-23
Observations regarding germination	Some germinated by 29th March, 1923, remaining observed till 2nd July, 1923.			
No. of tubers germinated ..	9	7	8	0
Percentage of germination ..	90	70	80	0

INCUBATOR EXPERIMENT.

TABLE XL.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 104°F. (40°C.).

B. TUBERS BURIED IN DRY EARTH.

Ten tubers are placed in a paper dish each heated for a definite time.

Date of starting, 20th March, 1923.

Table of weights (grammes).

	DURATION OF HEATING (DAYS)			
	3	7	8	14
	I B	II B	III B	IV B
Weight of 10 tubers before heating ..	19.15	16.84	16.35	19.01
Weight of 10 tubers after heating ..	15.22	10.36	9.63	11.29
Loss in weight	-3.93	-6.48	-6.72	-7.72
Percentage of loss in weight ..	-20.52	-38.47	-41.71	-40.61
Placed in a wet blotting paper for 24 hours				
Date	23-3-23	27-3-23	28-3-23	4-4-23
Weight after absorption of water ..	17.920	12.71	12.35	13.30
Change in original weight ..	-1.225	-4.13	-4.00	-5.71
Change in heated weight ..	+2.700	+2.35	+2.72	+2.01
Date of planting in soil two inches deep and watered daily ..	24-3-23	28-3-23	29-3-23	5-4-23
Observations regarding germination	Some germinated by 29th March, 1923, remaining observed till 2nd July, 1923.			
No. of tubers germinated ..	10	8	8	0
Percentage of germination ..	100	80	80	0

INCUBATOR EXPERIMENT.

TABLE XLI.

Experiment of heating the tubers in paper dishes in an incubator at a constant temperature of 104°F. (40°C.).

A. IN PAPER DISHES WITHOUT EARTH.

Date of starting, 5th April, 1923.

Table of weights (grammes).

	DURATION OF HEATING — 15 DAYS IN ALL CASES			
	I A	II A	III A	IV A
Weight of 10 tubers before heating..	10.50	10.82	12.10	10.60
Weight of 10 tubers after heating ..	6.10	6.89	7.10	6.88
Loss in weight	-4.40	-3.93	-5.00	-3.72
Percentage of loss in weight ..	-41.90	-36.31	-41.32	-35.09
Average		39.665		
Placed in a wet blotting paper for 24 hours on 20th April, 1923.				
Weight after absorption of water ..	6.63	7.73	7.32	7.52
Change in original weight ..	-3.87	-3.09	-4.88	-3.08
Change in heated weight ..	+0.53	+0.84	+0.22	+0.74
Date of planting in soil two inches deep and watered daily ..		21st April, 1923		
Observations regarding germination	Observed till 2nd July, 1923. Only one germinated on 1st May, 1923.			
No. of tubers germinated ..	0	0	1	0
Percentage of germination ..	0	0	10	0

INCUBATOR EXPERIMENT.

TABLE XLII.

Experiment of heating tubers in paper dishes in an incubator at a constant temperature of 104°F. (40°C.).

B. TUBERS BURIED IN DRY EARTH.

Date of starting, 5th April, 1923.

Table of weights (grammes).

	DURATION OF HEATING — 15 DAYS IN ALL CASES			
	I B	II B	III B	IV B
Weight of 10 tubers before heating ..	10.51	10.70	10.36	9.78
Weight of 10 tubers after heating ..	6.30	5.92	6.24	5.90
Loss in weight	-4.21	-4.78	-4.12	-3.88
Percentage of loss in weight ..	-40.05	-44.70	-39.77	-39.69
Average	41.052			
Placed in a wet blotting paper for 24 hours on 20th April, 1923.				
Weight after absorption of water ..	7.00	6.30	6.71	6.30
Change in original weight ..	-3.51	-4.40	-3.65	-3.48
Change in heated weight ..	+0.70	+0.38	+0.47	+0.40
Date of planting in soil two inches deep and watered	21st April, 1923.			
Observation regarding germination	Observed till 2nd July, 1923. No germination			
No. of tubers germinated ..	0	0	0	0
Percentage of germination ..	0	0	0	0

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

TO BE HAD FROM

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,
and from the following Agents :—

- | | |
|---|--|
| (1) THACKER, SPINK & CO., CALCUTTA. | (7) THACKER & CO., LTD., BOMBAY. |
| (2) W. NEWMAN & CO., CALCUTTA. | (8) SUNDER PANDURANG, BOMBAY. |
| (3) RAI M. C. SARKAR BAHADUR & SONS,
CALCUTTA. | (9) RAI SAHIB M. GULAB SINGH & SONS,
LAHORE. |
| (4) HIGGINBOTHAMS, LTD., MADRAS. | (10) MANAGER, EDUCATIONAL BOOK DEPOT,
NAGPUR. |
| (5) THOMPSON & CO., MADRAS. | |
| (6) D. B. TARAPOREVALA, SONS & CO.,
BOMBAY. | |

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the Agricultural Adviser to the Government of India, Pusa, Bihar, or from any of the above-mentioned Agents.

These publications are :—

1. *The Agricultural Journal of India.* A Journal dealing with subjects connected with agricultural economics, field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pests, fungus diseases, co-operative credit, agricultural cattle, farm implements, and other agricultural matters in India. Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Agricultural Adviser to the Government of India, and is issued once every two months or six times a year. *Annual Subscription.* Rs. 6 or 9s. 6d., including postage. Single copy, R. 1-8 or 2s.
2. Scientific Reports of the Agricultural Research Institute, Pusa.
3. Annual Review of Agricultural Operations in India.
4. Proceedings of the Board of Agriculture in India.
5. Proceedings of Sectional Meetings of the Board of Agriculture.
6. Memoirs of the Imperial Department of Agriculture in India.
 - (a) Botanical Series.
 - (b) Chemical Series.
 - (c) Entomological Series.
 - (d) Bacteriological Series.
 - (e) Veterinary Series.
7. Bulletins issued by the Agricultural Research Institute, Pusa.
8. Indigo Publications.
9. Books.

The following are the publications of the last two years :—

Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert and Secretary, Sugar Bureau), for the year 1922-23. Price, R. 1.

Scientific Reports of the Agricultural Research Institute, Pusa (including the Reports of the Imperial Dairy Expert, the Physiological Chemist, and the Secretary, Sugar Bureau), for the year 1923-24. Price, R. 1 or 1s. 8d.

AGRICULTURAL PUBLICATIONS—(concid.)

- Review of Agricultural Operations in India, 1921-22. Price, R. 1-4.
 Review of Agricultural Operations in India, 1922-23. Price, R. 1-10.
 Proceedings of the Board of Agriculture in India, held at Bangalore on 21st January, 1924, and following days (with appendices). Price, R. 1.
 Proceedings of the Cattle Conference held at Bangalore on 22nd and 23rd January, 1924 (with appendices), Price, As. 9.
 Report of the Proceedings of the Fifth Entomological Meeting, held at Pusa, 5th to 10th February, 1923. Price, Rs. 9-8.
 Proceedings of the Second Meeting of Veterinary Officers in India, held at Calcutta from 26th February to 2nd March, 1923 (with appendices). Price, R. 1-12.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

BOTANICAL SERIES

- | | | |
|----------------|------|--|
| Vol. XI, No. | IX. | A New Ginger Disease in Godavari District, by S. SUNDARARAMAN, M.A. Price, R. 1 or 1s. 4d. |
| Vol. XI, No. | X. | <i>Helminthosporium</i> spp. on Cereals and Sugarcane in India, Part I (Diseases of <i>Zea Mays</i> and <i>Sorghum vulgare</i> caused by species of <i>Helminthosporium</i>), by M. MITRA, M.Sc. Price, R. 1 or 1s. 4d. |
| Vol. XII, No. | I. | The Wheats of Bihar and Orissa, by ALBERT HOWARD, C.I.E., M.A., GABRIELLE L. C. HOWARD, M.A., and ABDUR RAHMAN KHAN. Price, As. 8 or 9d. |
| Vol. XII, No. | II. | I—History of the operations against Bud-Rot of Palms in South India.
II—Inoculation Experiments with <i>Phytophthora palmivora</i> Butl. on <i>Borassus flabellifer</i> Linn. and <i>Cocos nucifera</i> Linn., by W. McRAE, M.A., B.Sc. Price, R. 1-4 or 2s. |
| Vol. XII, No. | III. | Studies in Inheritance in Cotton, I. History of a cross between <i>G. herbaceum</i> and <i>G. neglectum</i> , by G. L. KOTTUR, M.A.G. Price, R. 1-4 or 1s. 9d. |
| Vol. XII, No. | IV. | Studies in Indian Oil Seeds. No. 2. Linseed, by GABRIELLE L. C. HOWARD, M.A., and ABDUR RAHMAN KHAN. Price, R. 1-4 or 2s. |
| Vol. XII, No. | V. | Studies in Gujarat Cottons, Part II, by MAGANLAL L. PATEL, B.A.G. Price, R. 1-12 or 3s. |
| Vol. XIII, No. | I. | Studies in Indian Tobaccos. No. 4.—Parthenocarp and Parthenogenesis in the varieties of <i>Nicotiana Tabacum</i> L. var. <i>Cuba</i> and var. <i>Mirodoto</i> , by GABRIELLE L. C. HOWARD, M.A.; and KASHI RAM. No. 5.—The Inheritance of Characters in <i>Nicotiana rustica</i> L., by GABRIELLE L. C. HOWARD, M.A. Price, Rs. 2 or 2s. 9d. |
| Vol. XIII, No. | II. | The Wilt Disease of Safflower, by S. D. JOSHI, B.Sc. Price, R. 1 or 1s. 6d. |
| Vol. XIII, No. | III. | Studies in Indian Fibre Plants. No. 3. On the Inheritance of Characters in <i>Hibiscus Sadderiffa</i> L., by ALBERT HOWARD, C.I.E., and GABRIELLE L. C. HOWARD, M.A. Price, Rs. 2 or 3s. |
| Vol. XIII, No. | IV. | The Mahali Disease of Coconuts in Malabar, by S. SUNDARARAMAN, M.A., and T. S. RAMAKRISHNAN, B.A. Price, As. 12 or 1s. |
| Vol. XIII, No. | V. | The Eradication of <i>Cyperus rotundus</i> L.: A Study in Pure and Applied Botany, by S. B. RANADE, B.A., M.Sc., and arranged and written by W. BURNS, D.Sc. Price, Rs. 2 or 3s. |
| Vol. XIII, No. | VI. | Studies in Diseases of the Jute Plant. (2) <i>Macrophoma Corchori</i> Saw., by F. J. F. SHAW, D.Sc., A.R.C.S., F.L.S. Price, As. 8 or 9d. |

CHEMICAL SERIES

- | | | |
|--------------|-----|---|
| Vol. VI, No. | VI. | Investigations on Indian Opium, No. 3. Studies in the Meconic Acid Content of Indian Opium, by HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E.A.C.: and MATHURA NATH BOSE, M.A. Price, As. 6 or 6d. |
|--------------|-----|---|

CHEMICAL SERIES—(concl'd.)

- Vol. VI, No. VII. Chemical Studies on Safflower Seed and its Germination, by V. A. TAMHANE, M.Sc., M.A. Price, As. 10 or 1s.
- Vol. VI, No. VIII. Note on the Permanent Manurial Plots, Coimbatore, by ROLAND V. NORRIS, D.Sc. Price, R. 1-4 or 1s. 9d.
- Vol. VII, No. I. A Note on Hydrocyanic Acid in the Burma Bean (*Phaseolus lunatus*, sp.), by F. J. WARTH, M.Sc., B.Sc. Price, As. 12 or 1s.
- Vol. VII, No. II. Studies of an Acid Soil in Assam, II, by A. A. MEGGITT, B.Sc. Price, As. 12 or 1s.
- Vol. VII, No. III. A Preliminary Note on the Decomposition of Calcium Cyanamide in South Indian Soils, by ROLAND V. NORRIS, D.Sc., F.I.C., B. VISWANATH and C. V. RAMASWAMI AYYAR, L.Ag. Price, As. 12 or 1s.
- Vol. VII, No. IV. Some Digestibility Trials on Indian Feeding Stuffs, by P. E. LANDER, M.A., D.Sc., A.L.C., and PANDIT LAL CHAND DHARMANI, L.Ag. Price, As. 12 or 1s.
- Vol. VII, No. V. The Buffer Action of Some Burma Soils, by J. CHARLTON, M.Sc. Price, As. 12 or 1s.
- Vol. VII, No. VI. Studies in the Chemistry of Sugarcane, II. Some Factors that determine the ripeness of Sugarcane, by B. VISWANATH, F.I.C., and S. KASHINATHA AYYAR, B.A. Price, As. 8 or 9d.
- Vol. VII, No. VII. The Phosphatic Nodules of Trichinopoly and the availability of Flour Phosphate as a Manure for Paddy, by RAO SAHIB M. R. RAMASWAMI SIVAN, B.A., dip. Agr. (*In the press.*)

ENTOMOLOGICAL SERIES

- Vol. VII, No. IX. Notes on Indian Diptera, by RONALD SENIOR-WHITE, F.E.S. Price, R. 1-12 or 2s. 3d.
- Vol. VII, No. X. *Platyedra gossypiella*, Saund., Pink Boll-worm in South India, 1920-21, by E. BALLARD, B.A., F.E.S. Price, As. 12 or 1s.
- Vol. VII, No. XI. Studies in Indian Dermaptera, by MORGAN HEBARD. Price, R. 1-4 or 1s. 9d.
- Vol. VII, No. XII. Further Notes on *Pemphres affinis*, Fst. (The Cotton Stem Weevil), by E. BALLARD, B.A., F.E.S. Price, R. 1 or 1s. 4d.
- Vol. VII, No. XIII. An Account of Experiments on the Control of *Siga* (*Schaenobius*) *incertellus* in the Godavari Delta, by E. BALLARD, B.A., F.E.S. Price, As. 14 or 1s. 4d.
- Vol. VIII, Nos. I, II & III. *Hydrophilidae* of India, by A. D'ORCHY-MONT; An Annotated List of Ichneumonidae in the Pusa Collection, by G. R. DUTT, B.A.; A Second Note on Odonata in the Pusa Collection, by MAJOR F. C. FRASER. Price, R. 1 or 1s. 6d.
- Vol. VIII, No. IV. Notes on Indian Muscidae, by R. SENIOR-WHITE, F.E.S. Price, As. 12 or 1s.
- Vol. VIII, Nos. V—IX. Papers on Indian Tabanidae, by P. V. ISAAC, B.A., D.I.C., M.Sc., F.E.S.; Two *Drosophilidae*, from Coimbatore and A New Aphidiphagous Fly, by J. R. MALLOCH; Notes on Indian Odonata in the Pusa Collection, by MAJOR F. C. FRASER, I.M.S.; On New and Old Oriental Cicindelidae, by Dr. WALTHER HORN. Price, R. 1-4 or 2s.

VETERINARY SERIES

- Vol. III, No. IV. Studies in Rinderpest, by W. A. POOL, M.B.O.V.S.; and T. M. DOYLE, F.R.C.V.S. Price, R. 1 or 1s. 4d.
- Vol. III, No. V. Etiology of Equine Contagious Abortion in India, by T. M. DOYLE, F.R.C.V.S. Price, As. 8 or 9d.

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA

- No. 138. Methods of Examination of certain Characters in Cotton, by G. R. HILSON, B.Sc. Price, As. 8.
- No. 139. List of Publications on Indian Entomology, 1920-21 (compiled by the Imperial Entomologist). Price, R. 1.
- No. 140. The Determination of Prussic Acid in Burma Beans (*Phaseolus lunatus*). Preliminary Note, by J. CHARLTON, B.Sc. Price, As. 3.

**BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH
INSTITUTE, PUSA—(concl'd.)**

- No. 141. Comparative Manurial Value of the whole plants and the different parts of Green Manures, by N. V. JOSHI, B.A., M.Sc., L.A.G. Price, As. 6.
- No. 142. The Cultivation of Lac in the Plains of India, by C. S. MISRA, B.A. Price, R. 1-8.
- No. 143. Ber (*Zizyphus jujuba*) Fruit and its Fly Pest, by J. L. KHARE, F.E.S. Price, As. 6.
- No. 144. Observations on the Morphology and Life-cycle of *Filaria recondita* Grassi, by M. ANANT NARAYAN RAO. Price, As. 6.
- No. 145. Some Observations on the Barren Soils of Lower Bari Doab Colony in the Punjab, by S. M. NASIR. Price, As. 3.
- No. 146. The Prevention of Nuisances caused by the Parboiling of Paddy, by J. CHARLTON, B.Sc., A.I.C. Price, As. 5.
- No. 147. List of Publications on Indian Entomology, 1922 (compiled by the Imperial Entomologist). Price, As. 7.
- No. 148. The Relative Responsibility of Physical Heat and Micro-organisms for the Hot Weather Rotting of Potatoes in Western India, by S. L. AJREKAR, B.A., and J. D. RANADIVE, B.A.G. Price, As. 5.
- No. 149. A Study of the Factors Operative in the value of Green Manure, by B. H. WILSON, B.A., I.E.S., P. E. LANDER, M.A., D.Sc., A.I.C., and M. MUKAND LAL, L.A.G. Price, As. 5.
- No. 150. The Improvement of Fodder and Forage in India (Papers read before a Joint Meeting of the Sections of Agriculture and Botany, Indian Science Congress, Lucknow, 1923), edited by GABRIELLE L. C. HOWARD, M.A. Price, As. 6.
- No. 151. A Method for the Accurate Determination of Carbonic Acid present as Carbonate in Soils, by PHANI BHUSAN SANYAL, M.Sc. Price, As. 2.
- No. 152. The External Morphology and Bionomics of the Commonest Indian Tick (*Hyalomma aegyptium*), by MOHAMMAD SHARIF, M.A., F.R.M.S. Price, R. 1.
- No. 153. Tamarind as a source of Alcohol and Tartaric Acid, by H. N. BATHAM, M.A., and L. S. NIGAM, L.A.G. Price, As. 3 or 4d.
- No. 154. The Bionomics of the Sarcopic Mange Parasite of the Buffalo with some observations concerning the relative power of resistance to adverse conditions of the different stages of the Acarus and of its egg, by T. M. TIMONEY, M.R.C.V.S. Price, As. 2.
- No. 155. List of Publications on Indian Entomology, 1923 (compiled by the Imperial Entomologist). Price, As. 11 or 1s.

INDIGO PUBLICATIONS

- No. 11. The Nature of changes occurring in the Indigo Steeping Vat, II, by W. A. DAVIS, B.Sc., A.C.G.I. Price, R. 1-10.
- No. 12. Indigo Experiments, 1922. (1) The effect on produce when vat liquor is allowed to stand in the beating vat and beating is delayed; (2) The effect of neutralizing the liquor with caustic soda before beating, by J. H. WALTON, M.A., M.Sc. Price, As. 4.

BOOKS

- Wheat in India, by ALBERT HOWARD, M.A., A.B.C.S., F.L.S., and GABRIELLE L. C. HOWARD, M.A. Price, Rs. 5 or 7s. 6d.
- A Description of the Imperial Bacteriological Laboratory, Muktesar: Its Work and Products, by MAJOR J. D. E. HOLMES, M.A., D.Sc., M.R.C.V.S. Price, As. 8 or 9d.
- Agriculture in India, by JAMES MACKENNA, M.A., I.C.S. Price, As. 4 or 5d.
- Some Diseases of Cattle in India. A Handbook for Stock-owners. Price, As. 8 or 9d.
- Report on the Diseases of Silkworms in India, by A. PRINGLE JAMESON, D.Sc. Price, Rs. 3.

NOTICE.

All new publications are included in the above list and are regularly posted to all on the mailing list as soon as issued. Unless complaints of non-receipt of any publication are received within six months of the date of issue, duplicate copies can be supplied only on payment of cost and postage.

